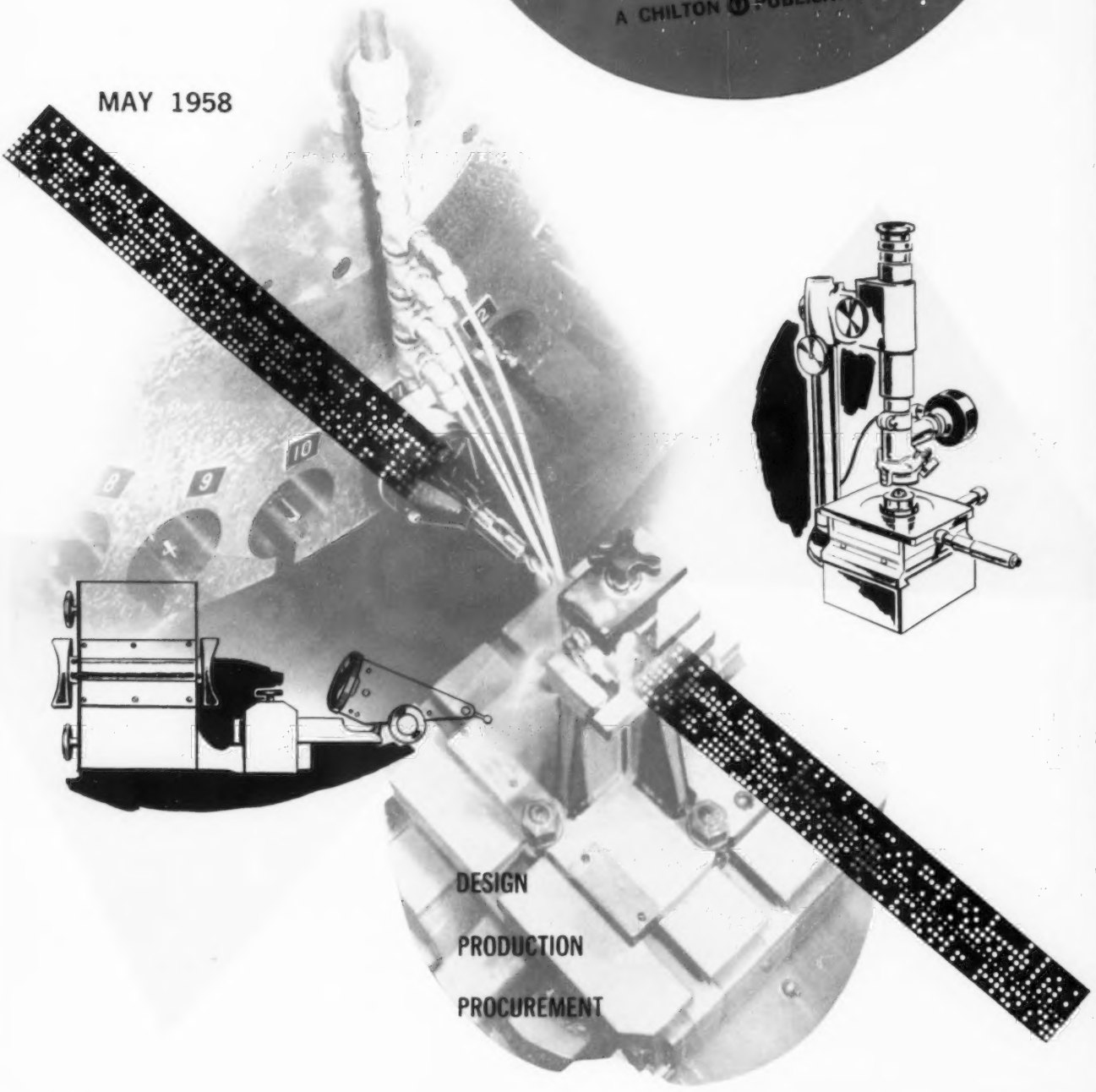
AIRCRAFT AND MISSILES MANUFACTURING

A CHILTON PUBLICATION

MAY 1958



DESIGN

PRODUCTION

PROCUREMENT

it's mainly a matter of TIMING!

The net cost of replacing a machine depends on WHEN you do it

THERE'S A TIME to buy and a time to sell. A time to invest and a time to "sit tight." And a time when you *should* replace an old machine with a new one.

Actually, timing is the most important factor in any replacement program. For there is one precisely predictable time when the replacement of any machine will work out to your best advantage—productionwise and investmentwise. Too soon is just as bad as too late. Either way you *lose money!*

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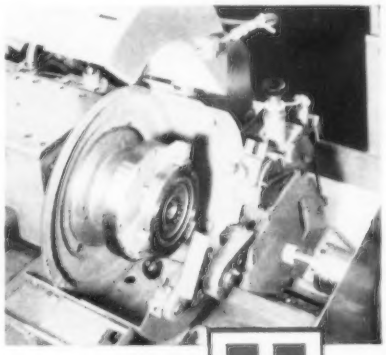
Power Consumption	427.00	182.00
Property Taxes & Insurance	45.00	552.00
Normal Maintenance	841.00	500.00
Restorative Repairs, Old Mach.	4,066.00	....
Capital Investment, New Mach.	....	6,256.00
Total Cost Per Year	$18,678.00	$12,569.00
Annual Saving, New Machine		$ 6,109.00



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MAY 1958

VOLUME 1, NUMBER 5

DESIGN
PRODUCTION
PROCUREMENT

A CHILTON PUBLICATION

THE COVER STORY

The producibility concept in the manufacture of aircraft and missile components has changed much of the design technology and has brought about revolutionary production processes. Automatic programming for machine tools is being utilized by the industry to achieve a high degree of uniformity and quality. Gaging is being carried out to the millionths, and constant tests are performed toward obtaining the ultimate—100 per cent reliability.

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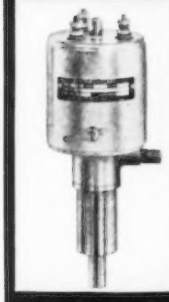

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Utilization of Engineers

Recently, the Engineering Manpower Commission held a meeting to discuss a number of subjects which should be of interest to every engineer.

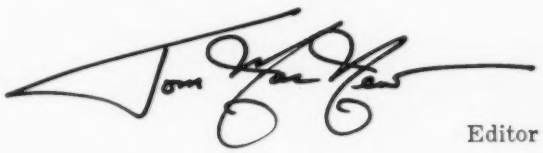
As a sideline to this meeting, the Engineering Manpower Commission agreed to continue its survey on engineers' salaries. This was formerly done every three years. Now, it is believed that it should be done every two years in order to have more timely information available for the industry.

The major subject discussed, however, was that of the utilization of engineers. One of the current complaints registered in this respect was against the government requirement for potential bidders to have technical manpower available before submittal of a bid for a research and development contract. Obviously, regardless of the number of bidders to a contract, the award thereof will finally be made to one contractor, and the remaining firms will end up with an excess of engineers on their hands. This problem is being taken under advisement, and as we understand it, certain recommendations are going to be made to the government.

Another problem on the use of engineers gets right back to salaries again. As you probably know, government contracts tend to equal-out the pay of all engineers operating under a specific contract. Therefore, in many cases, there is no allowance or incentive for better engineers.

It was also revealed that many companies are interested in a survey of industrial organizations on the use of their engineering manpower. It was agreed that such a survey could serve as a guide to various firms for the evaluation of their own programs. It was felt that with such criteria there would be many ways to reduce the present high turnover-rate of engineering personnel.

The above thoughts reflect just a few of the many aspects of this timely subject discussed at the meeting of the Engineering Manpower Commission. The proper use of these clues could go far in implementing re-evaluated means to utilize our technological manpower resources more effectively.



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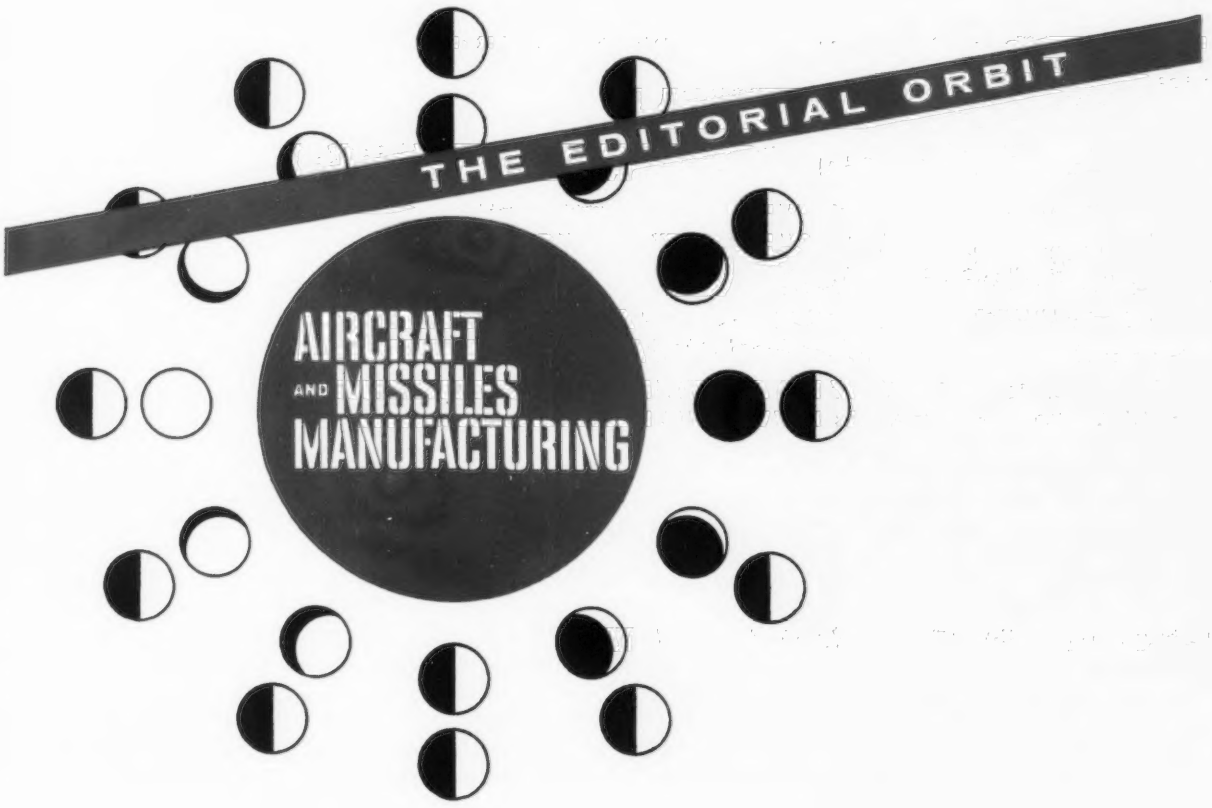

automated machine-tools

complex milling, drilling, and boring operations controlled by transistorized digital-computers from punched-tape information

Blue print specifications and call-outs can be translated into precision-machined aircraft and missile components by an all-electronically controlled line of machine tools, in the short time that is required for a typist to code a tape and feed it into an automatic machine-tool line.

The long lead-time customarily required for machined aircraft and missile components is substantially decreased by this forerunner of the completely-automated factory, which is operated from punched tapes and controlled by transistorized digital computers.

The first parts to be produced on the automated production line are vital parts of the Hughes armament control system used in several all-weather interceptor aircraft. A series of milling, drilling, and boring cutters are operated in proper sequence to shape the basic stock material as it moves down a belt-type line. The machine work-heads and the work-piece are rotatable to achieve the proper cutting angles.

Advantages

The advantages claimed for this automated machine-tool system are:

- Decreased lead-time in producing parts.
- Elimination of special jigs by requiring only simple holding fixtures.
- Elimination of almost all material handling by automatic transfer.
- Higher repetitive accuracy (precision) than is obtainable with manually-produced parts.
- Ability to simultaneously manufacture several different parts.
- Spare part and re-order runs may be simply and economically effected.

Flexibility

Any desired arrangement of machines (type and number of units) is possible to make up a line. Because of modular construction of

individual machines, it is possible to add a machine, remove a machine, replace a machine or rearrange the order of machines in the line.

Flexibility built into this electronically-controlled, automated line of machine tools permits simultaneous operations on an "inter-mix" of work-pieces. For example, it is possible, by inserting four different tapes in the three-machine line, to machine four entirely unrelated parts. This is the most practical application of the line insofar as tooling cost is concerned—only one work-holding fixture is required for each part. To machine a quantity run of an individual part on the line, four identical tapes would be needed. Because of the relatively low set-up time, a few parts in any sequence can be run through the line almost as inexpensively as several hundred parts.

Milling, Drilling, Boring

The milling machine is so arranged that the machine head can move in three axes, and the work-piece is secured to a pallet rotatable through 360 deg. Feed-speed is controlled and coordinated in all axes by electronics, through a range of 1 to 150 ipm. The machine itself is manufactured by Kearney and Trecker as are all other machines in the line. It is 88 x 66 x 22 in. in size and weighs about 20,000 lb. Feed movements in the three axes, longitudinal, vertical, and cross are 18, 12, and 12 in. respectively.

The boring bar on the boring machine is set to proper dimension by the control tape. It has two different spindles, to cover a wide range of hole sizes and to provide for a milling cutter to be inserted in the second spindle. Spindle speeds range from 50 to 500 rpm with a spindle horsepower of 5. The work-piece pallet is 12 x 12 in., and feed movements are 12 in. in each of the three axes.

The drilling machine has a magazine for housing 20 various-sized drills and taps. Each drill has its own drill-bushing which is extended when that particular drill is called upon to perform a step in the machining process. This eliminates the need for separate drill-boxes or plates for machining different parts. Should a drill or tap break in the machining cycle a safety is actuated to automatically retract the damaged

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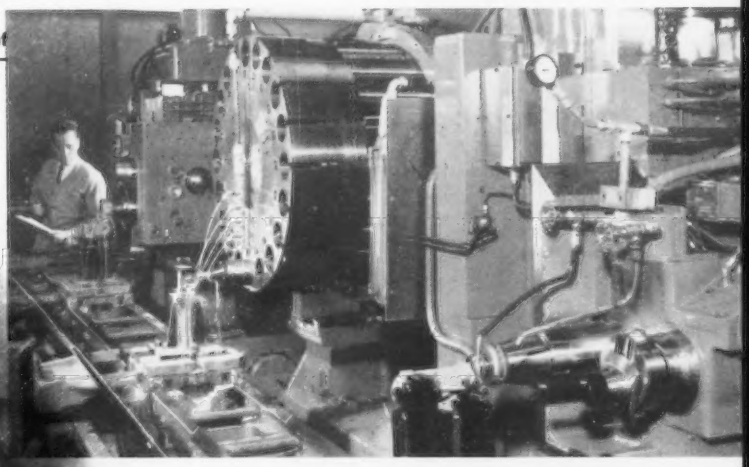
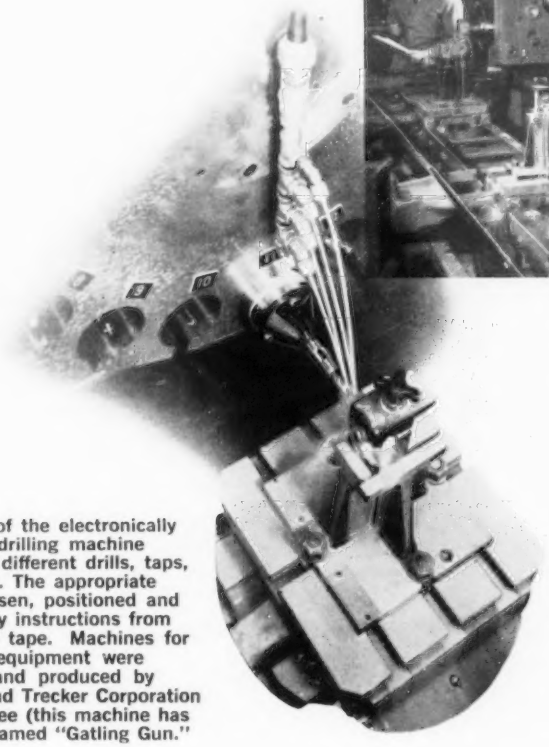


All the machined parts pictured can be manufactured simultaneously on the all-electronically controlled line of machine tools. Technician loads and unloads machine—all other operations are automatic. Provisions can also be made to handle these steps automatically.



Magazine of the electronically controlled drilling machine houses 20 different drills, taps, or reamers. The appropriate one is chosen, positioned and operated by instructions from a punched tape. Machines for portotype equipment were designed and produced by Kearney and Trecker Corporation of Milwaukee (this machine has been nicknamed "Gatling Gun."

Using standard blueprint, engineer draws up a planning sheet from which tape will be punched to deliver instructions to the Digitape controlled machine. Once data sheet is complete non-skilled personnel can cut the tape and load it into the machines.

automated machine-tools

continued

drill. Spindle speeds in the drilling machine are controllable in three ranges with a minimum of 110 rpm on the low range and maximum of 9000 rpm on the high range; power capabilities of the spindle are 5 hp.

Stores "Know-How" on Tape

Much has been made of the nation's production "know-how"; now it can be stored on a tape for use subsequent to the main production run or for communication between defense manufacturers.

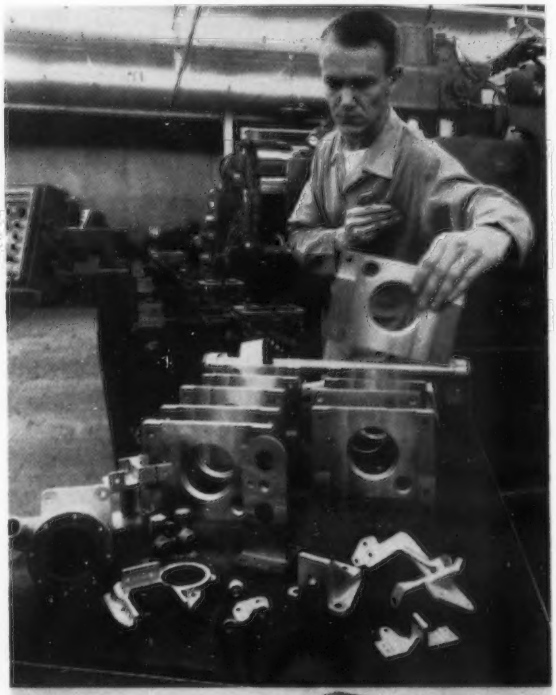
"Single machine-tools have been electronically controlled in the past, but this is the first successful application of automatic, electronic controls to a series of machine tools working on successive operations and, in fact, making a variety of parts."

Initial economic studies by Hughes indicated that the machine-tool line combined with the Digitape controls would be useful to the metalworking industry generally, and especially where only small quantities of parts are produced at one time.

The Digitape controls and machines comprise only a flexible prototype for fabricating essential parts of a production-line basis at Hughes' El Segundo plant. This system, with the same machine tools, will be installed permanently later in the year. It is sufficiently flexible to produce several, different, machined parts during a single run.

Production designs of both the controls and machines will be ready for delivery during 1958.

Three machines comprise the prototype automated line now in operation at Hughes Aircraft Co. Parts are mounted on rotatable work pallets and move down a special transfer bed between machines. Boring machine at right has dual heads, one doubling as a milling head, drilling machine in center houses 20 various sized drills or cutters, milling machine nearest operator has a head adjustable in three axes.



Parts produced are pictured with their respective control tapes. Set up is ideal for "canning know-how" after initial production of parts. For spare parts or short second production runs, tapes need only be removed from storage and fed back into the machine tool line.

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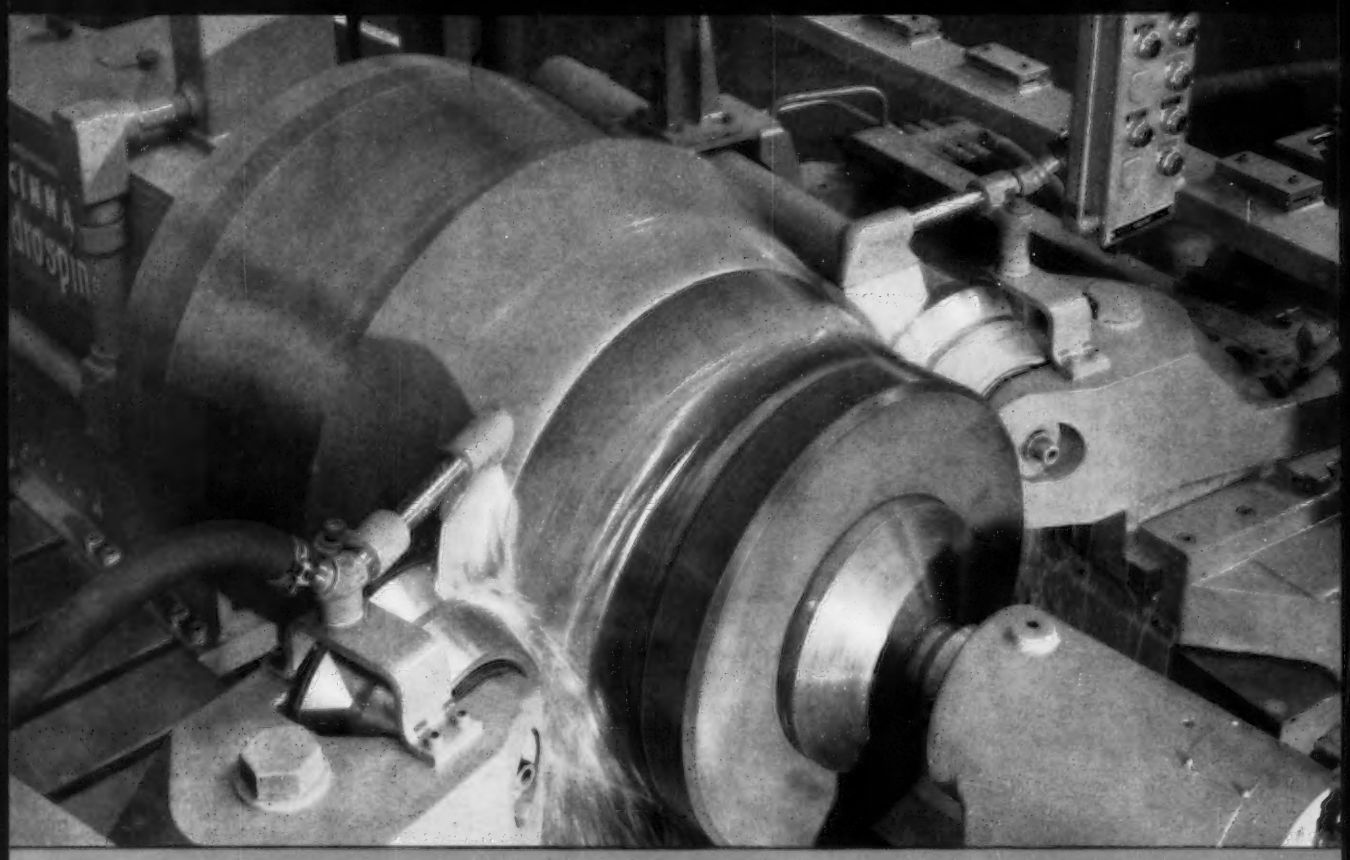
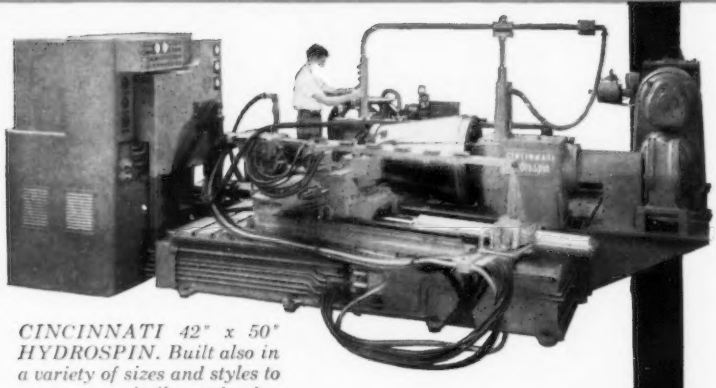
"Missile Age" machining is "Chipless"!





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THE CINCINNATI MILLING MACHINE CO.

CINCINNATI 9, OHIO, U. S. A.

missile fixtures

elaborate welding and trimming set-ups designed for repetitive accuracy on Jupiter

Jupiter IRBM is the largest missile for which the Army has developme responsibility. It has been estimated as 60 ft long and 8 ft in diam. It is powered by a 135,000 to 150,000 lb thrust liquid-fuel Rocketdyne engine.

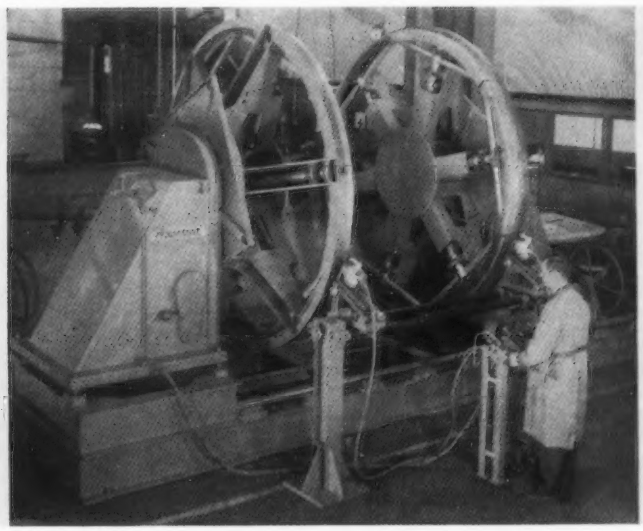

Fig. 1: Fixture used for trimming Jupiter IRBM main center section skins consists of a fixed power driven trunnion (left) and an idler trunnion. Idler is adjustable fore and aft on 16 ft rails. Fixture stands almost 12 ft high.

Welding has become a major fabrication technique in aircraft and missile manufacturing, chiefly because of the need for permanent seals in high-pressure, integral-tank, fuel systems, the need for aerodynamic cleanness, and the need for jointures capable of distributing over a wide area, the high stresses induced during maneuvering in supersonic flight.

Typical of these elaborate special tools and fixtures is the line radial welding, and routing fixtures designed by Progressive Welder Sales Co. for the fabrication of the main center section of the Jupiter IRBM. Four basic units are used to complete the following operations:

- Trim and weld cone to knuckle.
- Trim skin sections.
- Weld skin sections.
- Sample weld.

Fixtures Show Jupiter Size

No exact figures on the Jupiter IRBM size have ever been released, but it has been estimated at 50 to 60 ft in length, and about 8 ft in diameter. A study of the dimensions of fabrication fixtures will show that these dimensions are certainly not on the low side.

Trimming and welding the Jupiter's cone to the connecting knuckle is effected on a unit that consists of a power-driven trunion. Individual segments to be welded or routed are hand-loaded and securely clamped to the fixture. The routers are mounted on a separate rigidly-designed stand, and hence are not movable. Instead, the driven trunion is positioned to permit "tipping" the work piece into the router. The trunion is slowly rotated as the router trims the cone-knuckle segments.

A Linde welding unit is also mounted alongside the fixture to be readily accessible. Power supply for the welding operation is furnished by a Vickers component. The welding unit is mounted on manipulator which can be adjusted in all directions to effect weldments.

Physical dimensions of the fixture are: 10 ft diam by 10 ft height, weight is approximately five tons.

Trimming Fixture

Trimming of skin sections is effected on the tooling unit shown in Figs. 1 and 2. The unit consists of a fixed power driven trunion and an idler trunion. The idler trunion is mounted on rails approximately 16 ft long and it is adjustable fore and aft through this distance.

An air-operated, expanding mandrel is part of each trunion. Mounted alongside the trimming fixture is a fixed stand supporting two adjustable, air-driven, routers. Routing or trimming is effected by clamping the parts in place over the expanding mandrel (one end of the part attached to the driver trunion, the other to the idler), positioning the routers, and then slowly rotating the trunions. Entire circumferential sections of each missile can be made to match in this manner.

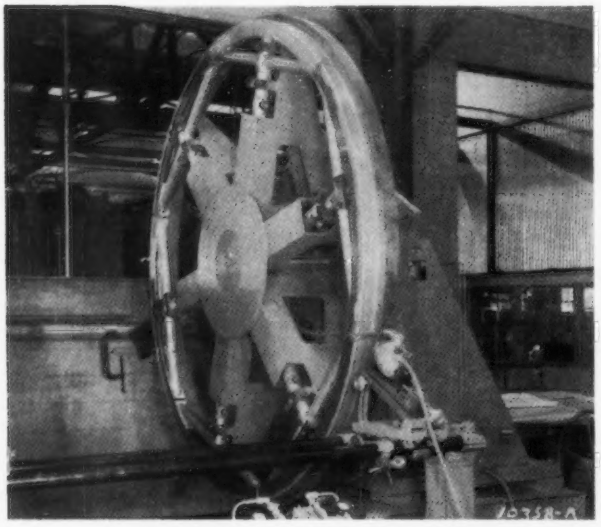

Fig. 2: Idler trunnion shown here and power trunnion both have air operated expanding mandrels, to which parts are attached. Routers are mounted on a fixed rail but are adjustable in all directions.

Welding Fixture

Circumferential welding of the Jupiter skin sections that make up the main center section of the missile is accomplished on the fixture shown in Figs. 3, 4 and 5. The unit consists of a driven trunion and an idler trunion, mounted on rails which allow fore and aft adjustment of approximately 60 ft. The driven trunion has a fixed spider for bolting on parts to be welded. The idler trunion is a hydraulically-operated traverse unit.

A center spindle on the driver trunion is power operated with a fore-and-aft adjustment of approximately two feet. Protruding through and beyond this unit is an expandable set of back-up rings for inert-gas welding.

Mounted on the 60-ft rails between the trunions (Fig. 4) are four cradles. Two of the

continued on next page

cradles are used to support the section being welded and the other two are used to support the new section to be added to the missile body. The latter two are adjustable vertically as well as horizontally.

Mounted alongside and parallel to this fixture is the manipulator which holds the welding unit and the remote control panel. The manipulator is adjustable in all directions. Power and gas supply for the welding are furnished by a Vickers unit; all operations are recorded and controlled through a floor-mounted console control. The immenseness of Jupiter can be estimated from the size of this fixture.

Weld Evaluation

Auxiliary sample-welding is done on the weld evaluation unit in Figs. 6 and 7. This unit is a driven trunion on which the work piece is mounted. The unit is placed at one end of the fixture used for welding skin sections and uses the same Linde welder, console, manipulator, remote station, and power supply. The unit is used to evaluate, or "prove-out" the welding procedure before welding actual missile components.

The physical dimensions of the unit are 12 ft in diam by 5 ft wide, with an approximate weight of 2½ tons.

Jupiter Status

A set of anti-slosh baffles were incorporated in the third Jupiter vehicle to hold fuel slosh to a minimum without interferring with fuel flow. The slosh problem linked to the first two Jupiter explosions. At the same time the gust sensing indicator mounted on the forward probe was removed, and a heat-blanket shield was installed at the base of the vehicle to prevent eddies of exhaust flame from burning out control wiring. The gas generator exhaust problem was solved by shifting from hydrogen peroxide decomposition to hot gas drive for auxiliary power turbine.

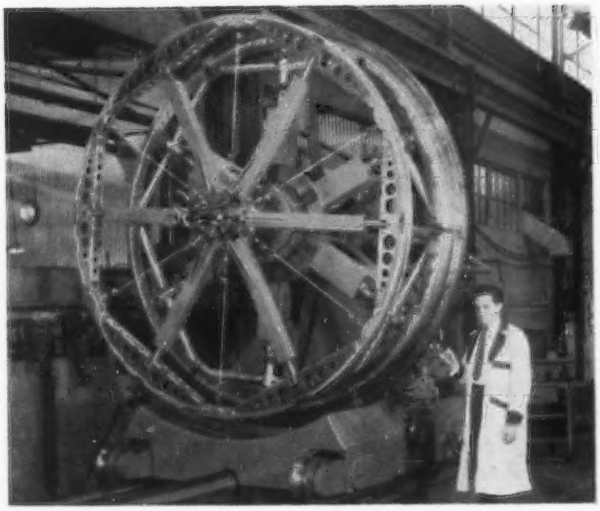

Fig. 5: Driver trunnion of the skin welding fixture has an expandable mandrel to which parts are attached, and an expandable welding back-up ring that is adjustable fore and aft.

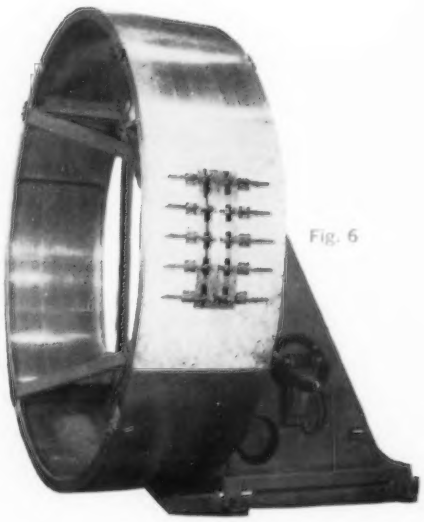

Fig. 6

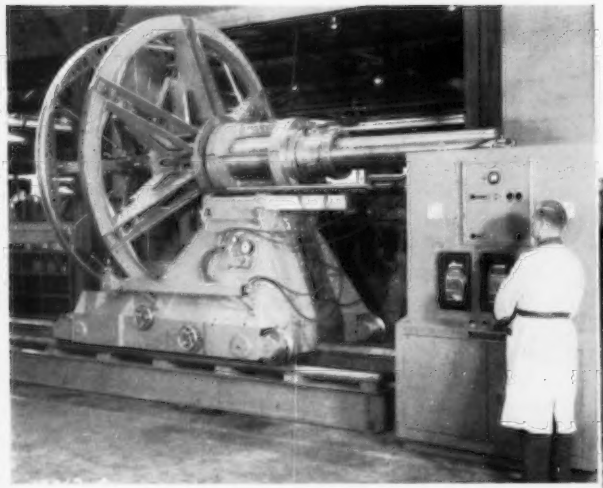

Fig. 4: All operations are controlled and recorded through a floor mounted console. Top of the driver trunnion is about 14 ft above floor level.

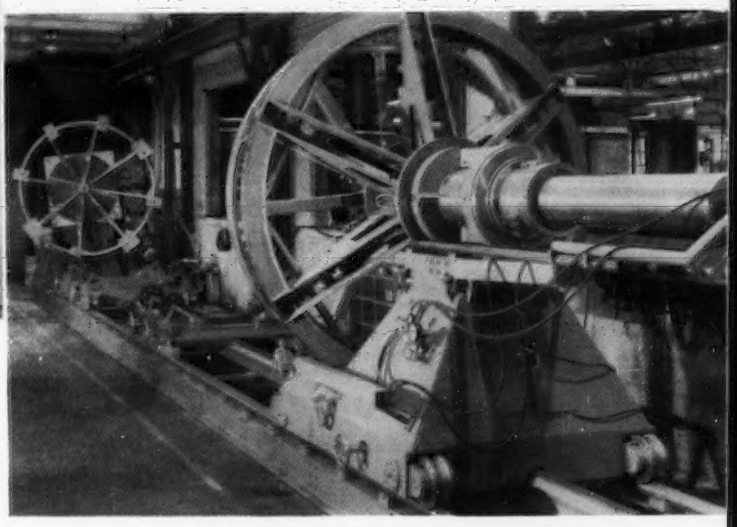

Fig. 3: Welding of missile skins is effected on this 60 ft long fixture. Foreground is the driver trunnion, and in the rear the idler. Four supporting cradles for missile components are adjustable between the trunnions.

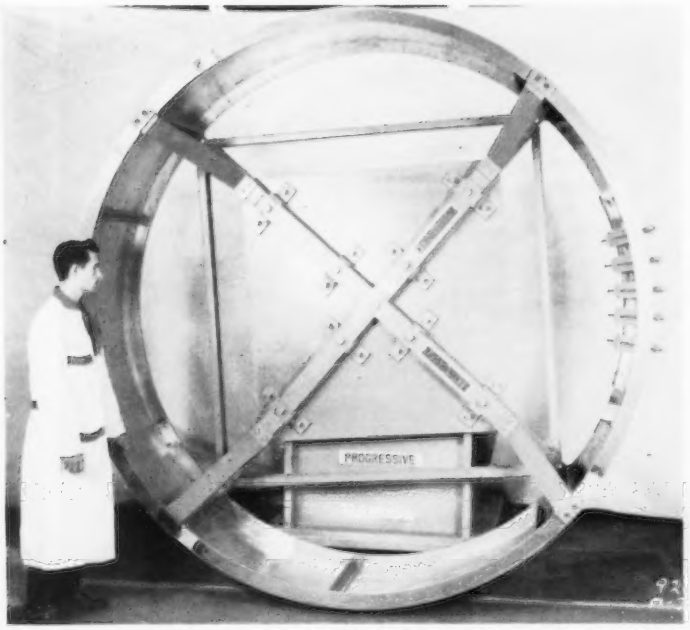

Fig. 6 and 7: Before actual missile components are joined, the welding process is evaluated on this sample-welding fixture. It is basically a power driven trunnion.

Extruded Shape Formed and Flash Butt-Welded . . . the Low-Cost Way to Make this 268 lb. Stainless Steel Ring

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rolling wide stainless sheets

hot-rolling of sandwich layup makes 120-in. wide stock available for production

There is little doubt that stainless steel is becoming the workhorse metal for structural applications in high speed aircraft and missiles. Among the many grades of stainless, the precipitation hardenable, semi-austentic class seems to hold the fancy of designers.

The greatest deterrent to full scale, economical utilization of these and other grades of stainless has been the inability of steel manufacturers to produce thin sheets of sufficient flatness and width to meet the needs of airframe manufacturers.

Now in evaluation stages at United States Steel Corp. (USS) is a "sandwich rolling" process which gives indications of being able to produce thin (0.025 in.) stainless steel sheets in widths up to 120 in. (previous limit was 48 in.) on a production basis using existing plate mill equipment. Gage control is described as good, meeting AISI standards in all cases, and bettering them in some.

Steels that have been successfully rolled are: 4340, five per cent chromium die steel, martensitic 12 MoV, and the semi-austenitic, precipitation hardening W stainless.

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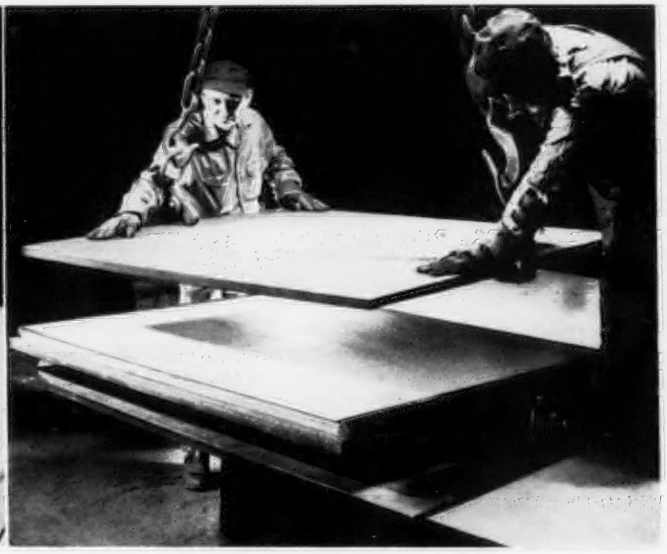
Four stainless steel plates are coated with a special separating compound to prevent fusing of the components during hot rolling.



Heavy (1 in.) carbon steel cover plates are placed over the stainless steel to complete the sandwich.

rolling wide stainless sheets continued

Sandwich is inspected before end and side bars are welded in place. The carbon steel cover plates are 1 in. thick, stainless steel plates are about 5/16 in. thick. Over 90 per cent reduction occurs during rolling, yielding plates 0.025 in. thick and 120 in. wide. Gage control is as good as, or better than AISI standards.

Sandwiching Technique Used

Sandwiching the stainless steel plates, and hot rolling, is the fabrication technique which has led to production of sheets in widths never before achieved in rolling.

Basic steps in the process are to: sandwich four stainless plates about 5/16 in. thick, coated with a special parting compound to prevent fusion of the plates during rolling, between two heavy (1 in.) carbon steel plates, then close the sandwich by welding inside and end bars; the sandwich assembly is heated in an oven to temperatures similar to those used for hot rolling (approx. 2200°F); the heated sandwich is rolled in single and/or multiple passes through a conventional plate rolling mill.

Over 90 per cent reduction of the stainless steel is achieved, yielding sheets with a nominal thickness of 0.025 in. with a plate area of 120 x 230 in.

Decarburization is satisfactory, and post rolling heat treatment renders the physical properties of the basic material virtually unchanged. The metallurgical mechanics of the process have varied explanations, the important factor however is this: in rolling, the sandwich structures have the working characteristics of the carbon steel cover plates rather than those of the sandwiched stainless inside. This fact makes little or no revamping of existing plate mills necessary in the way of adding more power or stiffening the rollers.

Anti-Fusion Compounds

To prevent the fusion of individual stainless steel plates during the rolling process, several compounds and methods of application have been evaluated. These processes are the direct outgrowth of earlier findings when USS developed techniques for strip-rolling stainless sandwich.

The layers of parting compound are applied to the stainless steel sheets and are usually composed of finely divided refractory material (magnesia) in a suspension, or slurry, with water. One commercial compound known as Luminite cement (calcium aluminate) has given good results.

From information published during the strip rolling investigation at USS it can be deduced that best results were obtained by swabbing the stainless plates with a 15 per cent solution of chromium sesqui-oxide (Cr_2O_3) as a primer, prior to applying the magnesia slurry.

The last named parting layer is used particularly when the ratio of total thickness of the stainless to the total thickness of the carbon steel cover plates is large. In this situation a high coefficient of friction is required between the components to prevent slippage.

The parting compound need only be applied to one side of each plate.

Industry Outlook

Aircraft like the North American X-15, and Convair B-58, make extensive use of stainless steel skins of 0.005 to 0.012 in. thickness. In the case of the B-58 (AMM, "Brazing Hustler's Stainless Sandwich," March 1958) the use of the stainless sheet (17-7 PH) in the fabrication of honeycomb sandwich makes the gage tolerances allowable extremely small. Overall deviation is ± 0.003 in. for the complete sandwich assembly. Facing

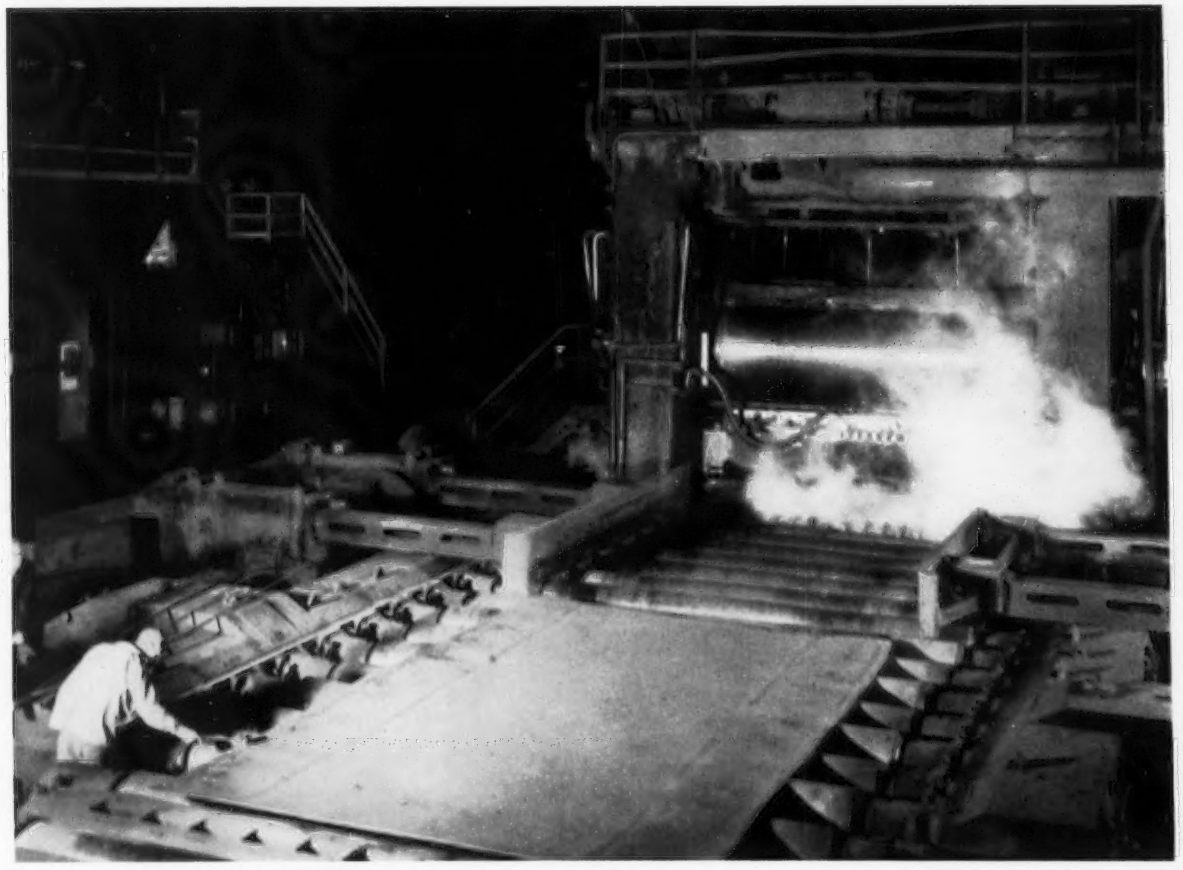
materials range from 0.005 to 0.012 in. and edge reinforcement members are as thick as 0.062 in.

Prior to announcement of the availability of new sheets the airframe manufacturers had varied comments. The 48 in. maximum widths were satisfactory to Boeing (Seattle), Convair (San Diego), Lockheed (Burbank), North American (Downey) Northrop, and Ryan, all were able to design with existing widths. Widths of 72 in. minimum were preferred by Lockheed (Sunnyvale), and North American (Los Angeles). Butt-welding sheets was a method being considered to cope with sheet width limitations.

All major airframe manufacturers had expressed a desire for 120 in. widths for future design, some had requirements as high as 150 in. widths.

Fully assembled sandwich is tack welded before machine welding side and end bars in place to seal all four sides of the sandwich. During rolling the assembly exhibits the working characteristics of the carbon steel cover plates rather than the stainless steel inside.

After oven heating to conventional hot rolling temperature, the sandwich is placed on the standard plate mill and rolle to 120 in. width. After cooling ends and sides are cut away to free the stainless steel sheets.



rocket casings deep drawn

large solid-propellant engine casings of steel and aluminum are made in one piece with varied wall thickness

by Robert McLarren

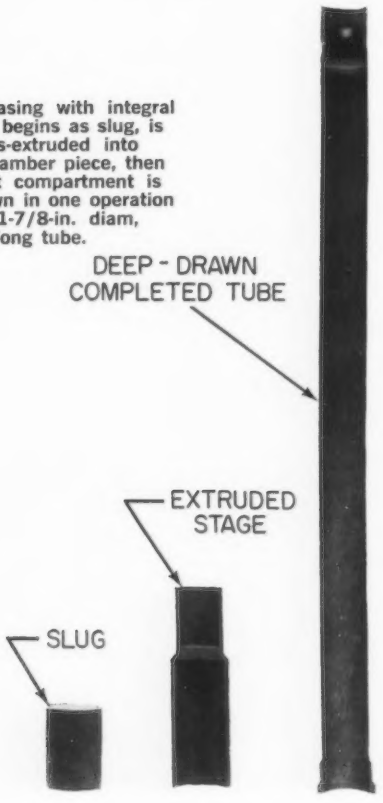
Solid-propellant rocket casings are being produced by the hundreds at the Norris-Thermador Corp. of Los Angeles, pioneers in deep drawing of steel cartridge cases.

The solid-propellant rocket, even to the size of the Polaris IRBM, is merely a large-scale version of the familiar cartridge, operating in reverse. Company engineers are confident that even the huge Polaris casing, which is several times the size of any similar unit so far produced, could be fabricated by deep-drawing if large equipment was made available.

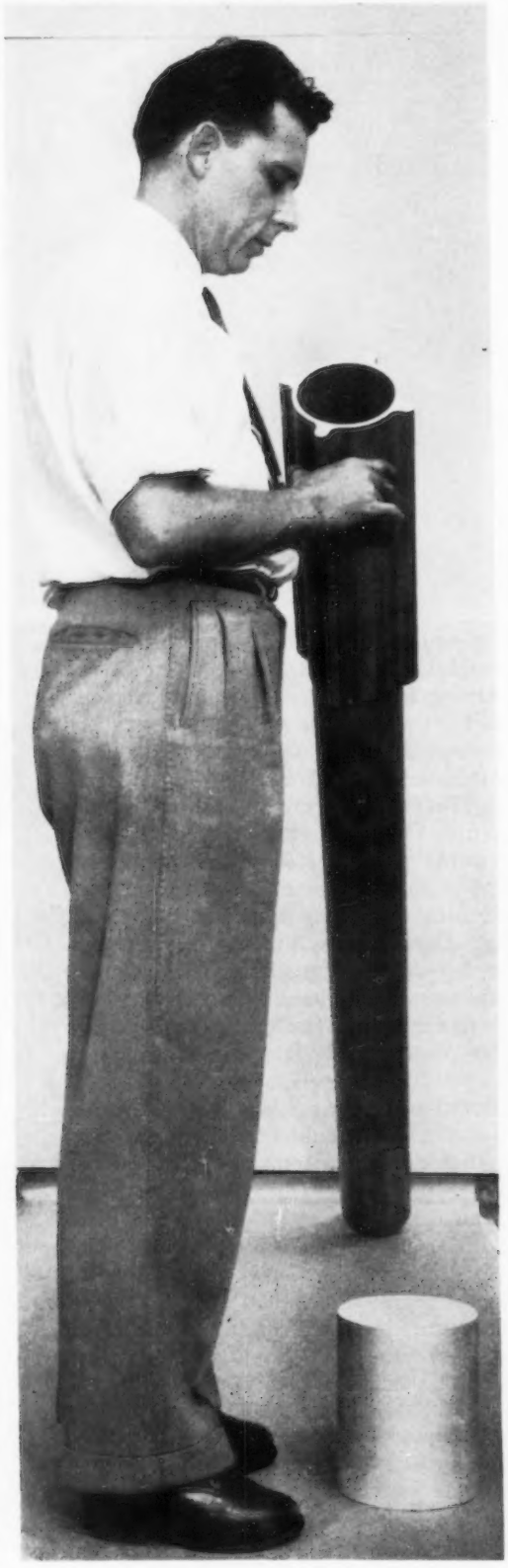
The Vernon (Calif.) Plant, Norris Division, has already produced in large quantities these casings for such air-to-air, solid-propellant missiles as the Sparrow, Sidewinder, Zuni, Falcon and Mighty Mouse, and is currently engaged in the production of such units for the Raytheon Hawk surface-to-air defensive missile. While the basic rocket casing or motor chamber of such missiles is simply a deep-drawn steel or aluminum tube, each incorporates certain internal features such as bulkheads, orifices recesses or variable

Array of rocket casings indicates range of applications for deep-drawing process. Norris-Thermador's Vice-President, George C. Ford, holds smaller samples drawn for 38 mm and 70 mm guns.

Missile casing with integral bulkhead begins as slug, is backwards-extruded into double-chamber piece, then propellant compartment is deep-drawn in one operation to form 1-7/8-in. diam, 27½-in. long tube.



Cold-extruded and drawn Sidewinder body, including integral fins, originates from aluminum-alloy slug shown below.



wall thicknesses peculiar to its operation. Thus, each tube requires extensive tooling of a specific nature before large-scale production can be initiated.

Production Planning

The planning of the drawing sequence starts with the finished design and proceeds backwards to the development of each preceding manufacturing operation. The maximum practical reduction in wall thickness, for steel, in a single draw is about 45 per cent, while the same for the diameter is 25 per cent; thus, necessitating the equation of two diverse factors while planning a successful drawing stage. Aluminum alloys may be similarly cold-worked, but generally to a lesser extent per operation. Both steel and aluminum may be cold-extruded with reductions of approximately 75 per cent in wall thickness in a single operation. Currently, rocket tubes 1⅞ in. in diam and 27½ in. long are being produced in a single extrusion operation, while preserving a mean wall-thickness variation of only 0.002 in., and a straightness within 0.020-in. TIR.

Few fabrication processes are governed so closely by the properties of the material as cold-working; practical relationships must be established between chemical analysis, metallurgical condition, and the drawing process under consideration. For example, experience has taught that the ideal carbon content of steel for deep-drawing is about 0.030; less carbon reduces the extent of hardness produced by the cold-working; higher carbon content promotes greater hardness, with consequent forming difficulties.

Hawk Tube World's Largest

The Hawk motor tube is fabricated from AISI 4130 machine steel, and has a drawn length of 96 in., with a diameter of 14 in., easily the largest deep-drawn cylinder ever produced. An unusual feature of this tube is the "step" halfway along its interior, at which point the wall thickness is reduced from 0.107 in. to 0.067 in. This is to accommodate the "two-stage" design of the solid-propellant motor.

The tube begins as a flat blank 42⅝ in. in diam and 0.281-in. thickness, which weighs 114 lb. These blanks are made from spheroidized rolled plate, which is first sheared into strips, then blanked in a press. The spheroidizing process is used to break up the pearlitic structure created by hot-rolling and thereby improve ductility. The blanks are then given an alkaline wash, and pickled in a sulphuric-acid solution to remove rust and scale. An inhibitor in the pickling solution is used to prevent hydrogen embrittlement. Thorough cleaning is essential in

continued on next page

Deep-drawing of Hawk tube begins with 114-lb, 42-in., 4130-steel blank which is "cupped" initially to "start" the material.

deep-drawing operations, since scale can create stress concentrations during the drawing process, and cause failure of the part.

After experimentation with literally hundreds of special lubricants, ordinary soap proved to be the most effective drawing-lubricant for normal operations. The blanks are passed through a hot soap-and-water bath on a conveyor, which then passes them over the top of the annealing ovens, the heat from which dries the soap quickly to provide a lubricant coating. For severe drawing operations, a phosphate coating plus a reactive soap-compound is used, to deposit a combination of separation and lubricating film on the blanks.

Cupping Isolates Faults

The first step in the actual forming operation is "cupping," in which the blank is formed into a shallow cup to "start" the material. This preliminary step was developed through practical experience, in an effort to isolate faulty blanks early, without risking costly drawing punches and dies. The cupping, which initially forms the material without change in thickness, serves to "upset" the material near the surface, and, as such, aggravates and reveals any hidden flaws. After the discrimination of faulty cups, the remaining sound ones are washed, then annealed in a one-hour cycle of heating, soaking, and cooling. The cups are then ready for the drawing presses.

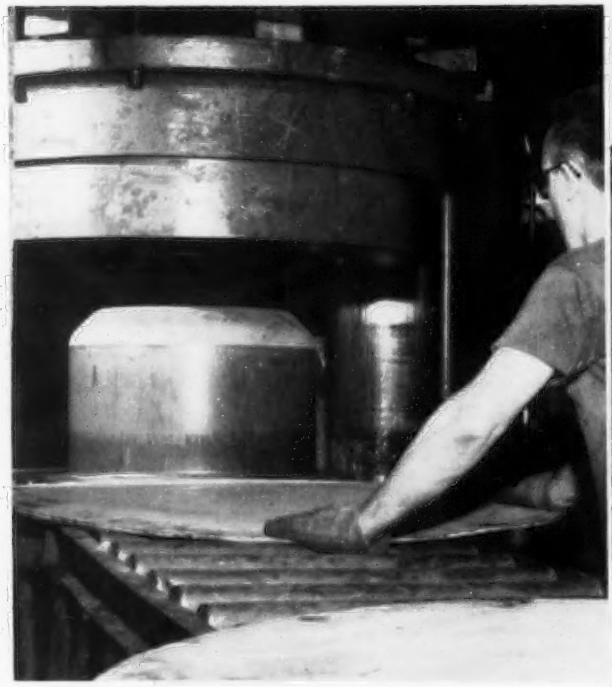
The drawing operation, in which the punch is forced down by hydraulic pressure against the part, and deep into the die, reduces both the diameter and the wall thickness of the part. Presses varying from 25-ton to 6000-ton capacity are utilized for this purpose. When the operation reduces the wall thickness only, without diameter reduction, it is classed as "ironing." On the Hawk tube there are two drawing and three ironing operations involved.

Following an initial drawing, the tube is subjected to a combination of drawing and ironing operation in which the part is first reduced by drawing, then passes directly down into a second die for the ironing action. The step in the wall thickness is produced by a corresponding step in the punch and in the die. After a second ironing, the "dead metal" is trimmed from the open end of the tube. This material results from the initial stressing of the perimeter grain-structure during the blanking operation which, following the drawing, comprised the upper periphery of the tube. This dead-metal area splinters, and can propagate cracks unless it is trimmed down to "live metal" in the tube.

After drawing, the tube is heat treated in an atmosphere furnace at 1650° F. Following heating, it is oil-quenched, then tempered at 850° F to attain the desired yield strength of 160,000 psi. The finished tube is then trimmed to a length of 83 in., and hydrostatic-pressure tested to 2200 psi in the 0.107-in. wall section, and to 1300 psi in the 0.067-in. section.

Aluminum Rocket Tubes

The greater adaptability of aluminum to



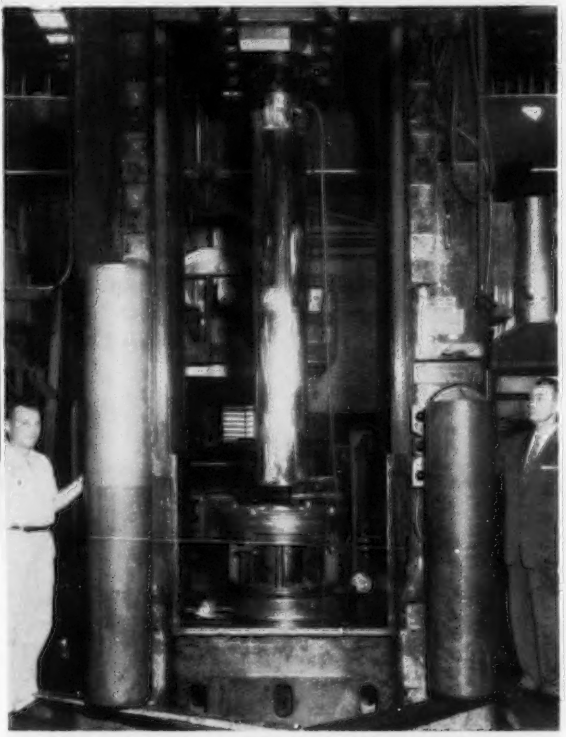
Close-up of "cupping" operation shows steel blank being rolled into hydraulic, die-and-punch press.

the cold-extrusion process permits the manufacture of parts in fewer steps than in steel; in some cases only a single operation is required.

Air-to-air missile tubes have been produced from 6061, 2014, and 7075 aluminum alloys. Some of these were in thin cross sections, and incorporated two chambers: a shallow chamber at the top with gas-pressure orifices, a solid bulkhead, and the main, long, powder chamber extending beyond. This double-chamber configuration is "started" by a backward-extrusion, in which the metal flows backward up the punch, to form the small chamber, and simultaneously cups the long chamber. The latter is then formed in a single deep-draw. The Sidewinder fixed rear-fin attachment ribs are also extruded as an integral part of the drawn tube, resulting in a one-piece missile motor, pressed from an aluminum alloy slug, with only the warhead and target-seeking equipment to be added.

Superior to Welded Tubes

Growing application of the deep-draw method of rocket-motor tube fabrication is rapidly replacing the conventional method, in which rolled plate is wrapped around a cylinder, and welded along one or more longitudinal and circumferential seams. Rocket-motor tubes must have virtually perfect performance reliability and welded assemblies in pressure-chamber bodies cannot as conveniently create the homogeneous metal structure and uniformity of metal thickness found in a drawn part.

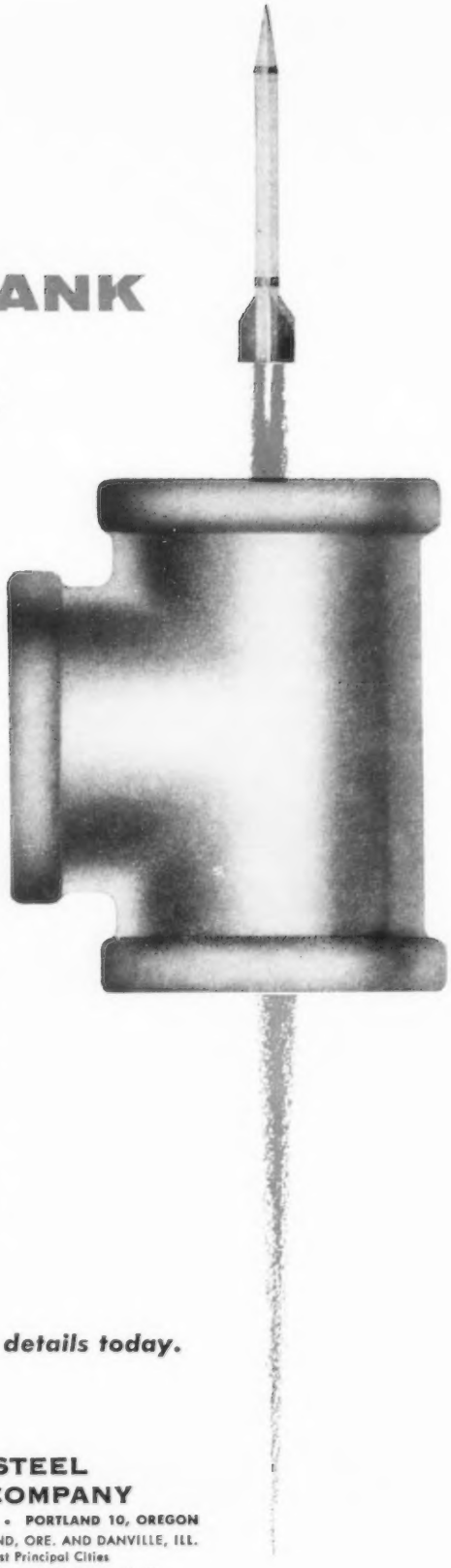


After deep-draw, tube is less than 5-ft long, has single wall thickness (right). Final draw extends length to more than 8 ft, reduces wall thickness at step (shown by color change at left). Color change is merely differential extension of exterior lubricant film caused by drawing operation.

Norris-Thermador Vernon plant utilizes variety of deep-drawing presses ranging from 25 to 6000-ton capacity.

FROM STORAGE TANK TO GUIDED MISSILE

AT MINUS
452 DEGREES



Transferring corrosive fuel from storage tanks to missiles at pressures over 10,000 psi and at temperatures as low as —452°, is just one of many problems *ESCO* is resolving with special heavy wall stainless steel fittings.

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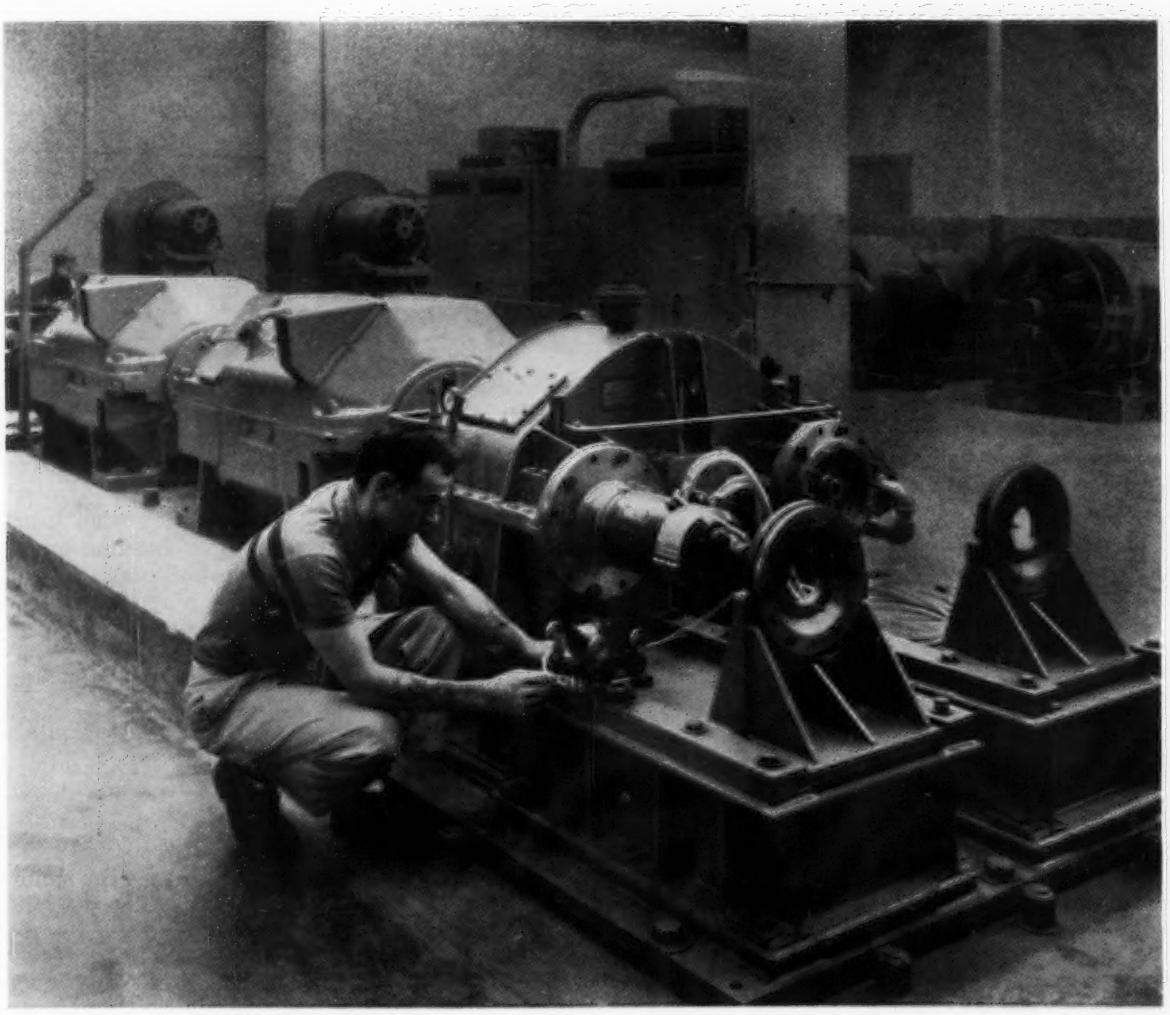

100/200 hp, 3000 to 9000 rpm test stand showing d-c generator mounted on output pad.

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high-performance test drives

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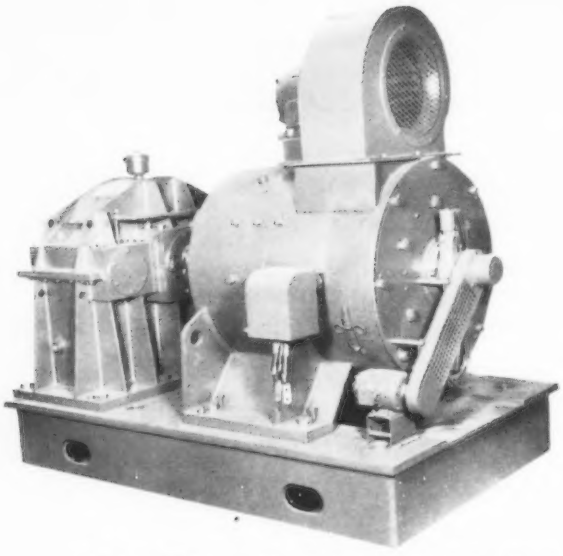

225-hp, 3000 to 9000 rpm test stand using a diesel motor as driving element.

Today, airplane electrical systems have over 100-kw capacities compared to a few kilowatts in 1940. Demands for increased electrical loads forced progress from a simple, single generator, d-c system to a multiple generator, 400-cycle, a-c system.

The present aircraft electrical systems were developed in the laboratories of the airframe and equipment manufacturers who have done an excellent job in keeping abreast of the requirements of high performance aircraft. Elaborate test facilities have been erected to simulate actual conditions on the aircraft. As the requirements for airborne apparatus became more stringent, so did the requirements for the test apparatus.

Aircraft Equipment Preferable

To test aircraft electrical components and systems completely and accurately, it is desirable to use aircraft generating and regulating equipment in mock-up with other system components. The use of non-aircraft type (i.e., industrial type) generating equipment produces an electrical power-supply which does not accurately represent the aircraft system.

Airborne alternators, in actual service, are usually driven by the aircraft engines through a gear train. In some cases, the alternators are driven by air turbines or an auxiliary engine. Therefore, if an aircraft electrical system is to be reproduced in a laboratory, an alternator prime-mover must be supplied to simulate the aircraft engine performance through all conditions of flight. Electric drives, rather than aircraft engines, are preferred as prime-movers because of low operating cost, low maintenance, availability, and ease of operation.

Necessary Characteristics

To simulate an aircraft engine, an electric drive must have the following characteristics: wide operating-speed range; low transient-speed deviation with suddenly-applied loads; fast recovery-time; variable rates of acceleration and deceleration; and low steady-state speed regulation.

The above requirements are the essential considerations in a regulated electrical system, and it would be in order at this point to discuss how these factors influence the selection of the drive equipment.

Perhaps the most difficult requirement for the drive, to be met within reasonable economic and physical limits, is the maximum transient-speed deviation and recovery time. Transient-speed deviation is usually defined by expressing the change in speed, for the first swing which occurs when load is applied, as a percentage of the original set speed. Recovery time is the interval between the application of the impact-load, and the return of the drive-speed to within the steady-state regulation limits.

Basic Considerations

On an unregulated d-c motor, with constant field flux, the torque is directly proportional to armature current, and counter-emf is directly proportional to speed. At any instant the net voltage-producing armature-current is equal to the algebraic sum of the bus-voltage, the counter-emf, and the reactance-voltage which is produced by the armature-inductance and changing armature-current. When load is instantly applied, the speed of the motor begins to drop at a rate determined by the magnitude of the applied load, the mechanical inertia of the motor, and the connected load. As the speed of the motor drops, the counter-emf drops in direct-proportion and time-phase with the speed; the difference between bus-voltage and counter-emf produces armature-current whose build-up is limited by the reactance-voltage. This explains why the motor-speed overshoots the unregulated motor-speed until the current reaches full load, at which time the motor begins to speed-up again till it settles at the full-load steady-state speed.

Impact-Drop Computation

It is possible to calculate impact-drop directly from a simple relationship; in most cases

good accuracy will be obtained by using the following equation:

$$D_i = \frac{IR \times 44}{V}\left(2 + \frac{T_a}{T_o}\right) \quad (1)$$

D_i = impact-load speed-drop
R = resistance of armature-circuit
I = rated current
T_a = armature time-constant
T_o = mechanical time-constant

The mechanical time-constant, T_o, is analogous to electrical time-constants where current in an L-R circuit approaches the ultimate steady-state value in accordance with an exponential relationship. If armature-inductance, friction, and load are zero, the speed of a shunt-wound, d-c motor follows the same exponential curve when a constant voltage is applied. In one time-constant, the speed reaches 63.2 per cent of the ultimate steady-state value. T_o may be calculated from the following equation:

$$T_o = \frac{WK^2 \times IR \times rpm^2}{308 \times 5250 \times HP \times V} \quad (2)$$

Equations (1) and (2) above show that for a given horsepower and voltage rating, there are three factors which affect the transient performance of a motor: armature-resistance, inductance, and WK^2. These can be adjusted to suit the requirements of the application.

If low impact-drop is of prime consideration, maximum results can usually be obtained by reducing the IR drop. This factor appears directly in equation (1); also indirectly, it is one of the factors which determines T_o in equation (2). Reducing armature-resistance tends to increase the factor T_a, but this effect on the total equation is small if compared with the direct effect the quantity R has outside the brackets.

Speed Regulation

In most applications, the user is interested in maintaining a set speed under all types of loading conditions. This requires a regulating system. However, regulator theory is quite complex, and an adequate development of the application factors would be beyond the scope of this article. Nevertheless, it would be timely to discuss some of the parameters which affect the regulating system.

Recovery-time was defined as the time-interval between load application and recovery of speed, to within the regulated limits. It was shown that the maximum transient-deviation is a function of the motor and load inertias, and the inherent regulation of the d-c machine. Practically speaking, the regulator has no effect on the maximum transient-speed deviation, but it does directly affect recovery time. The mechanical time-constant T_o, the field time-constant, and the system-gain largely determine what the recovery-time will be.

Control console for 100-hp drive stand. Auxiliary control center is in the background.

One of the problems the designer must face is the contradiction between the requirements for low impact-drop and fast recovery-time. A large amount of inertia would tend to reduce the impact-drop, but would lengthen the recovery-time. A small amount of inertia would, of course, have the opposite effect. The optimum system is usually achieved only after a careful consideration of all the factors, and one or several computer studies.

Additional Requirements

Another requirement of test-stand drives is a wide operating-speed range which seriously affects the obtainable performance. First of all, a wide speed-range directly affects the steady-state regulation. When a motor is operating at full-voltage and full-field, the armature IR-drop is from 5 to 10 per cent of the armature voltage. The regulation from no-load to full-load will be about the same amount. If the speed is reduced to 1/5, by reduction of armature voltage, the IR-drop will remain the same as in full-load current but the percentage will have increased by five times. If the same maximum steady-state deviation in per cent is specified over the 5 to 1 range, then the regulator will require five times the gain at minimum speed, that would be required at top speed. However, if the speed-range weakens the motor field, the IR-drop will remain a constant percentage, and no added regulator gain will be required.

The speed-range also has an effect on the peak-load transient-deviation. Up to base speed,

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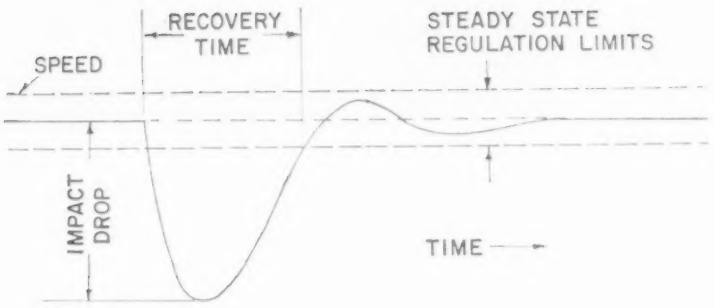
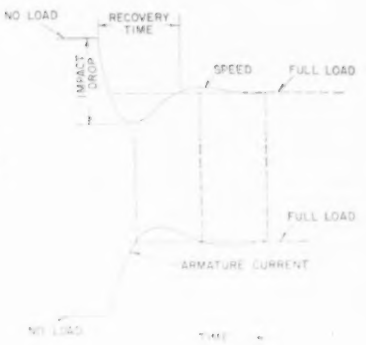
Transient variations of speed with instantly-applied load on a regulated d-c drive.



Transient variation of speed and armature current with instantly-applied load on an unregulated d-c drive.



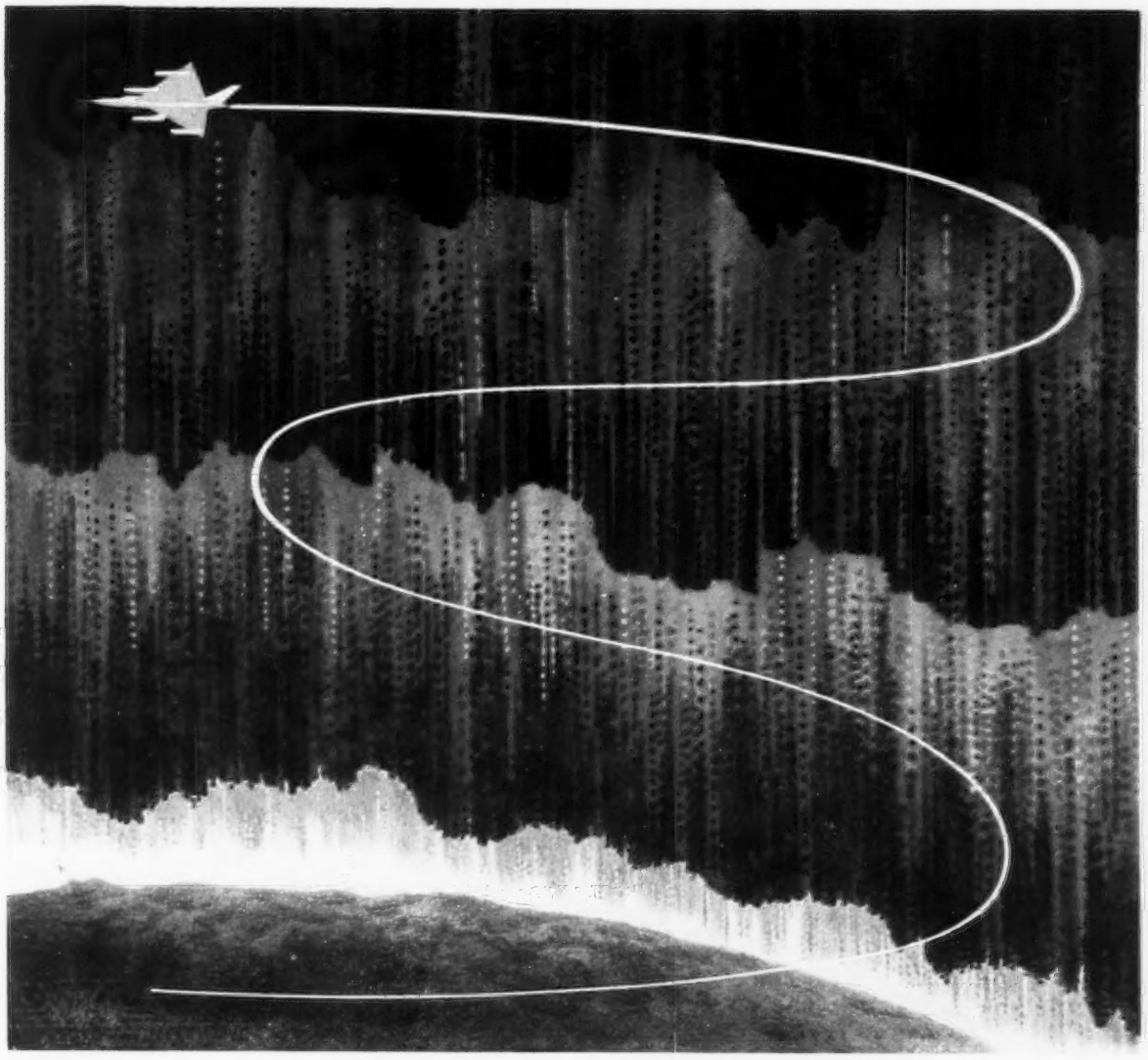
it is closely related to the armature IR-drop of the motor. Since the armature time-constant, T_a, increases as the square of the speed, as the field is weakened above base speed, the percentage peak-load transient-deviation will be less than the percentage armature IR-drop.

Acceleration Problems

There is another requirement for test-stand drives, which if taken by itself would not be very difficult to meet, but in combination with low impact-drop and recovery-time would make the selection of drive equipment extremely difficult. The rapid acceleration rates required, sometimes up to 4000 rpm/sec with rated load, can be attained quite readily by a variable voltage-control, with full motor field-strength which gives a constant accelerating torque. The impact-drop which may be acceptable at the top speed will not be acceptable at the minimum speed because, as stated above, the per cent IR-drop and the speed deviation will increase inversely as the speed is reduced with full field.

If the speed-range is accomplished by field-control only, the transient-speed deviation and recovery-time will be acceptable but the acceleration rate will not be maintained over the speed-range because the torque decreases directly as the speed increases. This again is another example of the contradictions which plague the system designer. Obviously, a compromise must be reached where either the high accelerating-rate, the low transient-deviation, or possibly the speed-range will be sacrificed in order to get the most desired characteristic.

The problem of selecting electrical-drive equipment to comply with the foregoing requirements is not a simple matter, and the successful application depends on a thorough knowledge of the requirements and a careful consideration of all the factors influencing system performance.



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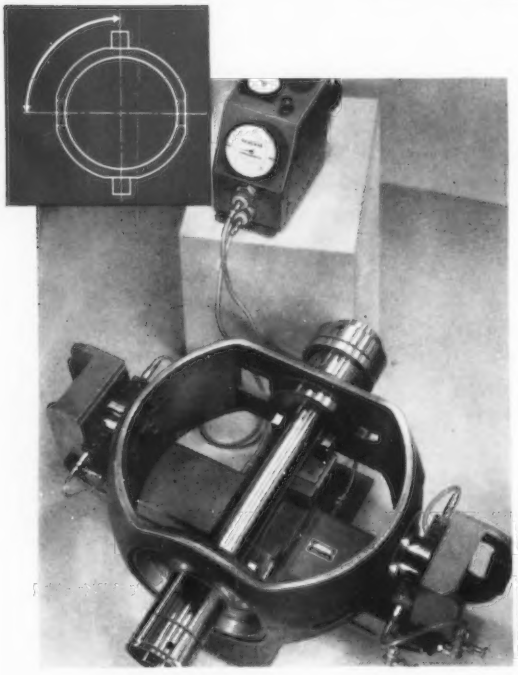

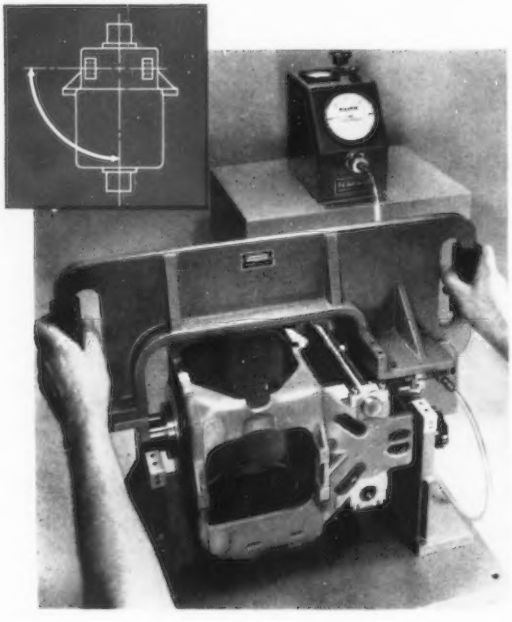

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Air gage and cradle fixture check guidance gimbals of surface-to-surface missile for squareness of pivot axis to bore axis, one of many critical measurements required. Bores locate on precision mandrel resting in V-blocks. AirProbe contacts shift position if any deviation from 90° relationship occurs. Corresponding change in balance of air meter is easily read on dial graduated in .00005" which spreads out tolerance (±.0005" in 20") over half the dial.

Platform which rides in the gimbals shown in other illustration also has numerous critical relationships, one of which is being gaged here. The axis of the platform pivots must square within .0005" in 20" to the axis of the bores in which gyros will mount. V-blocks in portable C frame fixture locate on pivots of platform held in special cradle. AirProbe contact responds to any lack of squareness. Amount shows up on air gage dial graduated in .00005".

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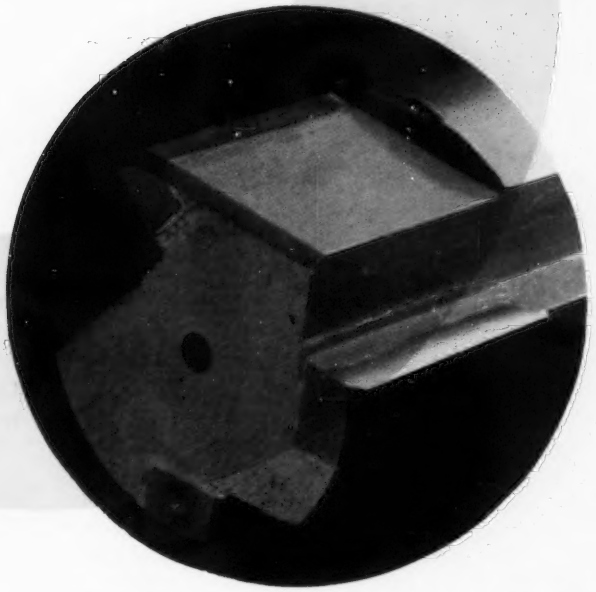
improved reaming tool

adaptation of gun-drill combines reaming and polishing operations

by Ronald A. Cole



Features of dual-purpose reamer developed by Short Brothers & Harland Ltd.

The increased use of high-strength materials in the construction of aircraft and missiles has slowed down component production, increased scrappage due to poor quality finish, and increased production costs. One of the big problems in aircraft and missile manufacture is the consistent production of holes with negligible ovality, straightness, and a high quality of surface finish. It has been found that the ordinary fluted reamer will not give a consistent finish on hard metals, also that it is prone to wear and breakage due to chip-clogging in a long bore. In many cases boring on a lathe has provided the only answer although an expensive one.

Short Brothers & Harland, Ireland, battled with the problem for a long time until their tool research department came out with a new adaptation on the old-fashioned "gun drill." This unusual tool was considered worthy a try for a variety of reasons: it had previously provided a good finish and accurate alignment for firearms, and if it could be applied successfully in this field, it would have the attraction of being cheap to produce.

Initial check runs on steel were unsuccessful. Modifications suggested by the appearance of the bores were made. These included grinding back the chamfer on the rubbing pads so that the cutting edge led by 0.010 in. and reducing the body diameter so that the rubbing pads projected by 0.020 in. to give better chip clearance.

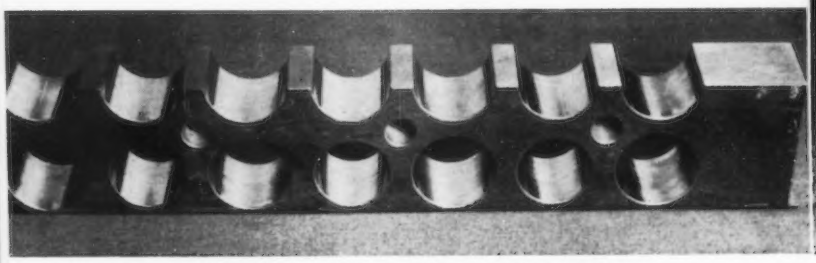
As a result, the second test produced accurate holes but with rather poor surface finish. Experiments with feed, speeds and cutting fluids showed that above a certain speed, finish was always good provided a rather course feed was

continued on next page

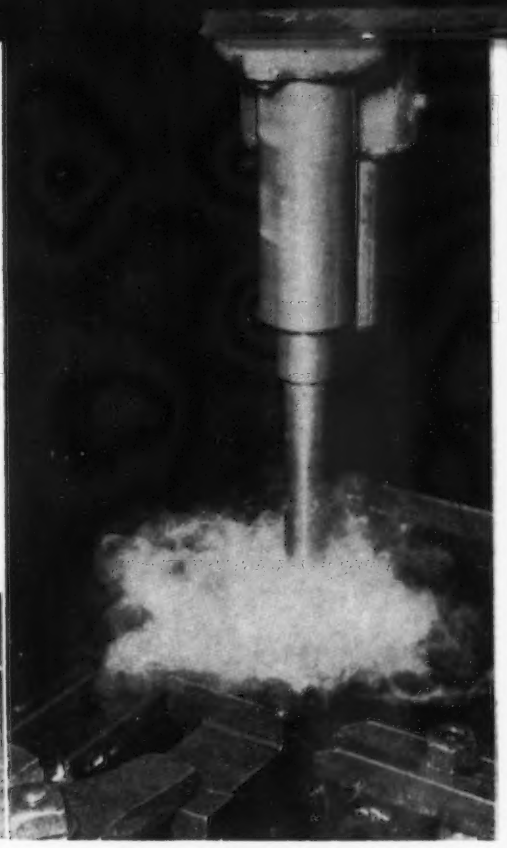
improved reaming tool

continued

Landing-gear component reveals holes reamed by the Short method.



Series of 1-in. diam holes reamed in stainless steel at 1048 and 1480 rpm, with a feed of 0.01 in./rev.



Reamer in operation on an aircraft rudder-bar component

employed. Chip removal in long ribbon form was no problem, however fluid was used for purging and cooling purposes. Fluid characteristics are unimportant for this application but there must be a copious supply. This latter requirement is very important because two of the three carbide tips brazed to the shaft are purely rubbing pads. These give a burnishing effect which produces high temperatures; a cloud of steam envelops the job while cutting.

The first production job was the reaming of two holes in a 90-ton steel forging for the Britannia. Previously this had to be done on a lathe at considerable expense. The 1⅜ and 1½-in. holes were reamed at 600 rpm with a feed of 0.0008 in./rev. This gave a surface finish of 5 micro inches and impeccable accuracy of bore.

More tools were then made conforming to a wider range of sizes and of slightly modified design to represent the final pattern. They featured a fluted body for better heat dissipation through a higher coolant flow. Extensive tests on a wide range of metals including stainless steels and Meehanite cast iron were then run using a small drilling machine. Reportedly, a speed between 250 and 350 surface ft/min is suitable for most metals, and the surface finish varies directly with the feed rate. If this is varied between 0.004 to 0.010 in./rev. the finish ranges from 3 to 10 micro inches. Brass and cast iron should be cut dry with heavy feeds.

Holes over ½-in. diameter should have 1/32 in. left on the diameter for cleanup; for smaller holes 1/64 in. is usually sufficient. Should the reamer be used in conjunction with a jig, then the bushing must allow a large volume of fluid through for cooling purposes.

Such reamers can be made in any machine shop equipped for tip brazing. They are presently being marketed by Serco Ltd., London. Advice to those making their own is as follows: steel for the body must be a good nickel-chrome-moly alloy, heat treated to about 200,000 psi UTS. This is turned to 0.040 in. under the bore diameter, then three flutes are milled along its length, and recesses provided for the three tips. Once these are brazed in place cylindrical grinding produces the exact diameter and a 45 deg chamfer on the ends. On the cutting edge this chamfer may lead by 0.005 to 0.010 in., compared to that on the rubbing pads. By this method an overall cost lower than that for conventional fluted reamers is obtained; touching up the small cutting edge is all the re-grinding necessary.

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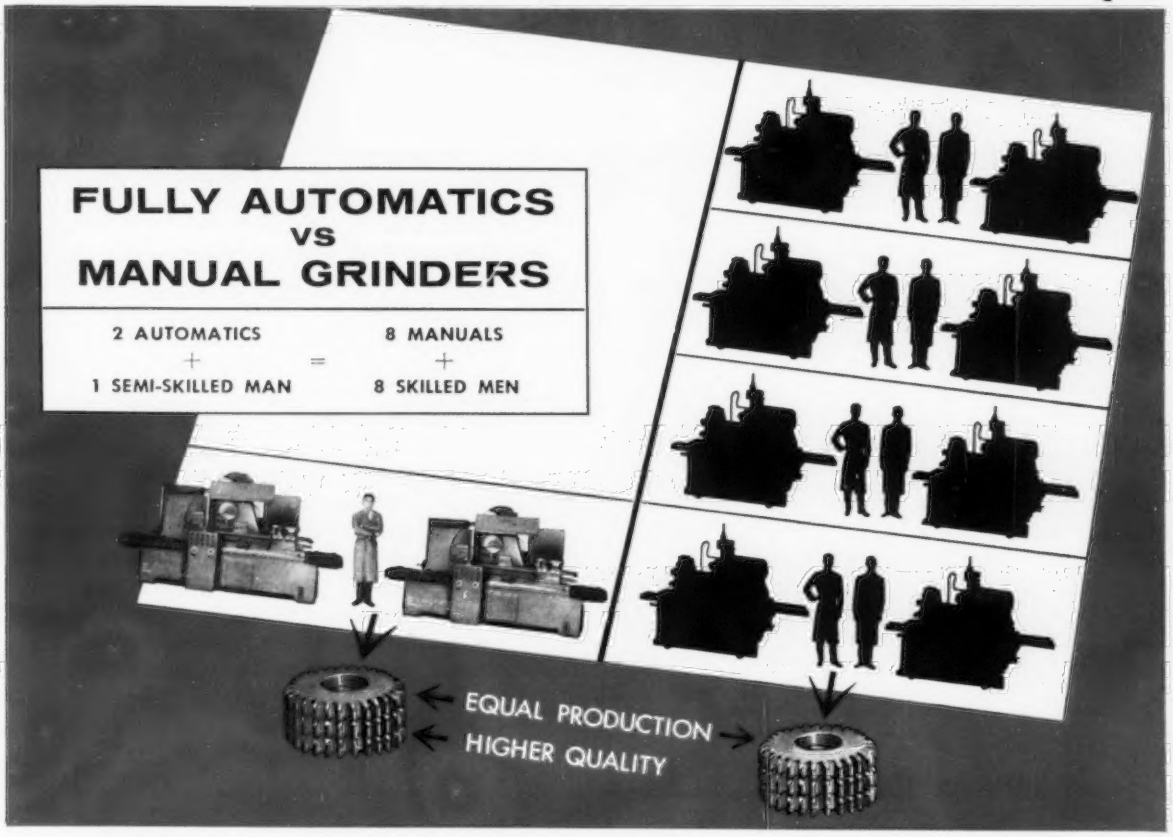

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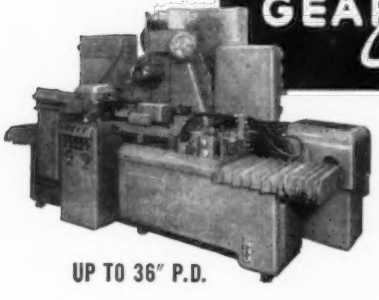

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TRENDS IN

high-temperature metals

stainless steel remains workhorse for structural applications; new alloys need refinement before full-scale acceptance

by Julius J. Harwood, Chief, Metallurgy Branch
Office of Naval Research

The success of the scientific and technological revolution which is occurring in this country, and the world at large, is in a large part dependent on progress in materials research, materials development, and design.

Limitations in present-day materials technology represents the chief obstacle to the development of advanced aircraft and missiles, the utilization of nuclear energy and other sources of power, and of new industrial processes. Whether the materials problems are associated with space flight, supersonic aircraft, missiles, nuclear reactors, electronic devices, or new industrial processes, there is always one problem common to all —the need for materials with higher temperature resistance and stability.

The two principal sources of high temperature in aerial vehicles are:

- Aerodynamic heating, resulting from friction between the surface of the aircraft and the air molecules passing over it.
- The exothermic reactions occurring in propulsion systems.

Aerodynamic Heating

Aerodynamic heating is influenced by vehicle velocity, density of the atmosphere (altitude), nature of the boundary layer adjacent to the skin (laminar or turbulent), and the emissivity characteristics of the material. From Figure 1 it can be seen that for sustained flight at

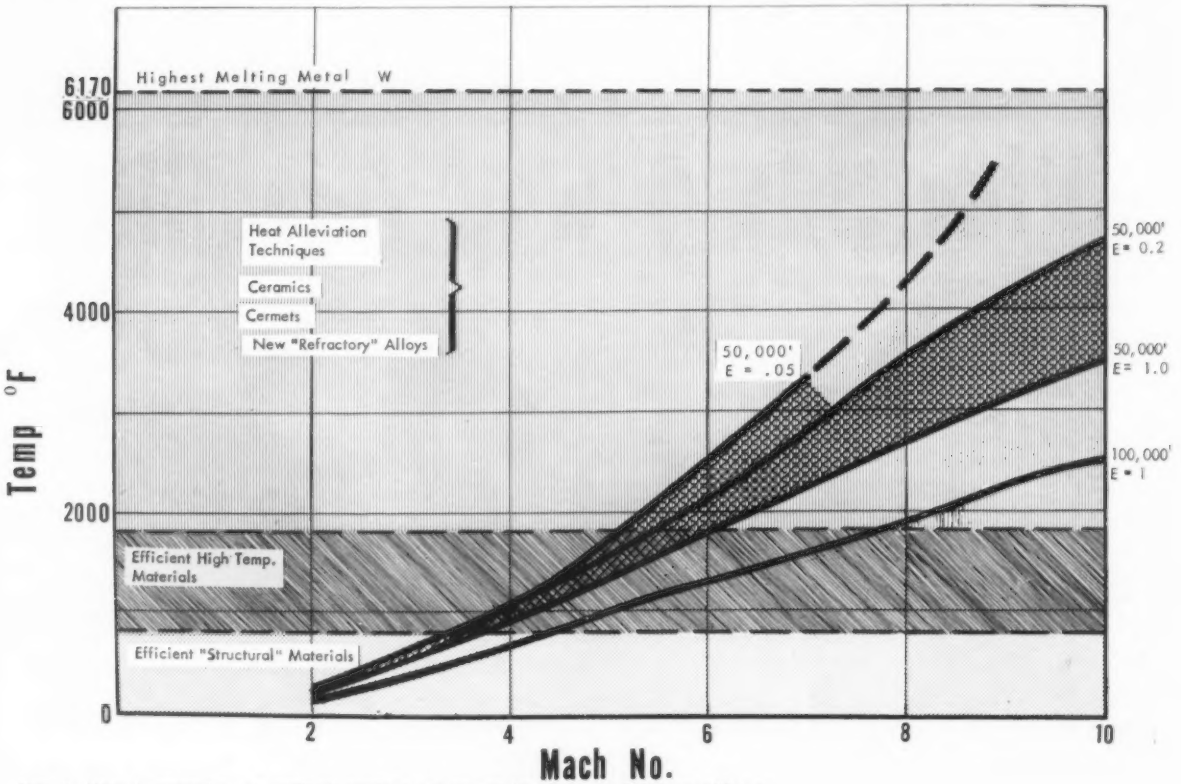


Fig. 1. Skin temperature is plotted against air speed for various flight conditions. It can be seen that as speeds approach Mach 4 existing structural materials are no longer efficient.

Mach 2, skin temperatures in the order of 500°F can be anticipated, at Mach 4, 1000°F can be expected, and at Mach 8 the calculated stagnation temperatures are above the melting points of all known, useful structural metals. At Mach 15 to 25, which are the reentry speeds of ballistic missiles, temperatures may rise to 25,000°F.

At these temperatures physical properties are sought in metals that are not considered for normal use. In addition to strength, modulus of elasticity, and strength-to-weight ratio, such factors as thermal conductivity, coefficient of thermal expansion, surface emissivity, oxidation-resistance, and temperature-dependence properties become important.

Propulsion System Heating

Paralleling the increase in airframe operating temperatures has been the growing trend in aircraft gas-turbines toward higher compression ratios and "hotter" fuels, with a resultant increase in combustion temperature and turbine inlet temperature.

The temperature range of 300 to 1200°F, to be expected on airframe sections is also within the operating requirements of the compressor stages of gas turbines. Despite the differences in methods of fabrication, the same classes of alloys are receiving consideration for both areas of application.

Aluminum Alloys

Aluminum alloys have been the basic structural metal for airframe construction since the advent of the metal airplane. Their good strength-to-weight ratio makes them still useful structural materials in most areas of aircraft that do not exceed Mach 2. Above the temperatures encountered here, their strength properties deteriorate rapidly.

The heat-treatable aluminum alloys have better physicals at low temperatures, but above 200°F, for example, 2024 in the T86 temper condition (cold worked 6 per cent and artificially aged) shows superior physicals to the 7075-T6 alloy.

Several experimental aluminum alloys show interesting properties up to 800°F. Among these are X2219 (6.0 per cent Cu, 0.3 per cent Mn, 0.1 per cent V, and 0.15 per cent Zr), good for wrought applications, and XA140 (8.0 per cent Cu, 6.0 per cent Mg, 0.5 per cent Mn, and 0.5 per cent Ni), good for casting applications.

With the exception of powder metallurgy, dispersion-hardened aluminum alloys, the degree of improvement possible of aluminum alloys will probably not extend it beyond 600-800°F applications.

In the field of powder-metallurgy, sintered

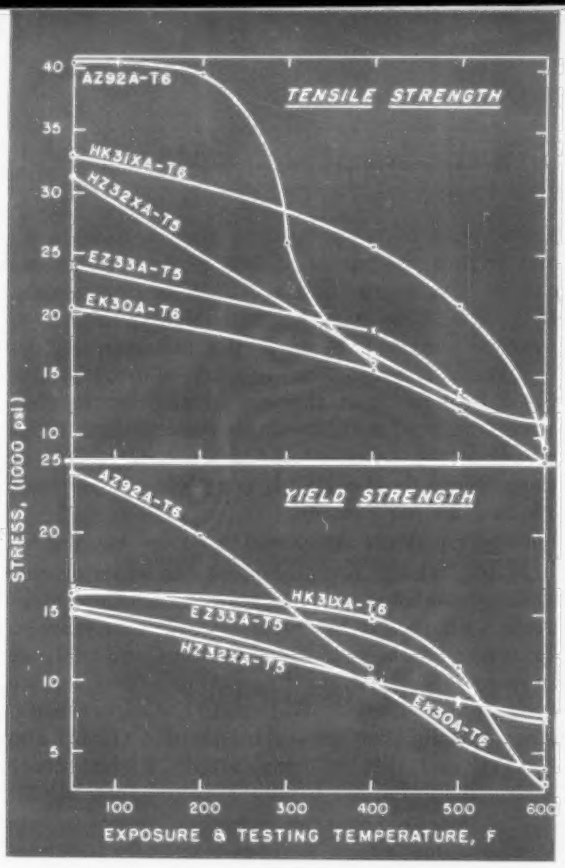


Fig. 2. Tensile and yield strengths for magnesium alloys are plotted against temperature (1000 hr exposure and tested at temperature) for separately cast test bars.

aluminum powder (SAP), has demonstrated superior strength properties above 500°F and the ability to retain room-temperature properties even after exposure as high as 900°F. However, tendencies toward brittleness, particularly in the presence of notches, have limited their application. Alcoa designations are M257(APM) and M276(APM). In composition they are almost equivalent to 2S aluminum, but contain 8 to 16 per cent finely-dispersed aluminum oxide. Typical room-temperature properties are:

Tensile strength	50,000 psi
Yield strength	32 to 36 ksi
Elongation	8 to 10 per cent
Reduced	10 to 12 per cent

Success in the SAP development program has led to the extension of the strengthening principle of powder metallurgy to copper, nickel, magnesium, molybdenum and other metals.

Magnesium alloys

Despite low densities, magnesium alloys have had limited usage in aircraft and missile structures because of inferior corrosion-resistance when compared with aluminum. However, the introduction of several new wrought and casting

continued on next page

alloys, with better properties than aluminum alloys within the range of 600 to 800°F, has enhanced the competitive position of magnesium (Fig. 2). The major contribution in improved elevated-temperature properties has been the development of magnesium-thorium alloys, containing 2 to 3 per cent thorium in addition to zinc, zirconium, and manganese as conventional alloying elements. One of the more outstanding of these alloys is the HK31, containing 3 per cent Th, and 0.7 per cent Zr.

The HK31 alloy can be heat treated, is weldable, readily formable, and has superior corrosion resistance as compared with other magnesium alloys. It has received wide and successful usage as sheet, plate, extrusions and castings in ramjet engines involving rather severe service conditions. Magnesium alloys in the experimental stage contain thorium and manganese (HM31 and HM21) and display considerably higher creep strength in the 400 to 800°F range than HK31.

Despite these encouraging improvements in magnesium alloys, it appears unlikely that conventional alloy approaches will yield other than marginal improvements. One may anticipate increased usage for moderate-temperature ranges, particularly for applications in which castings are suitable; but for highly-stressed, higher-temperature requirements, little consideration is afforded to magnesium alloys.

Titanium Alloys

The early over-optimism that prevailed about titanium has now settled down to a more realistic appraisal of its potentialities as a structural material. There is little question that titanium alloys can occupy an important position as structural materials in the range of 300 to 1000°F. The investment of one to two billion dollars in its development by government and industry has led to development of alloys in almost every desired commercial form, with strengths comparable to those of high-strength steels and weights of about 40 per cent less.

The strength-to-weight superiority of titanium alloys in comparison with other materials is shown in Figs. 3 and 4. This outstanding advantage of titanium has led to definite production applications in airframes and in jet engines, either as sheet or forgings. The J75 engine used titanium alloys for compressor discs, blades, and other components. The two most popular titanium alloys are A110-AT alloy, containing aluminum and tin, and the 6 Al-4 V alloy containing aluminum and vanadium. The former is an all alpha, non-heat-treatable alloy which is formable and readily weldable, and available primarily as sheet. The 6 Al-4 V alloy is an alpha-beta alloy, heat-treatable to room-temperature strength levels of 175,000 psi. It was primarily developed as a forging alloy for compressor applications but is

Fig. 3. Yield strengths per weight of various alloys being used in aircraft and missile manufacturing are plotted against temperature.

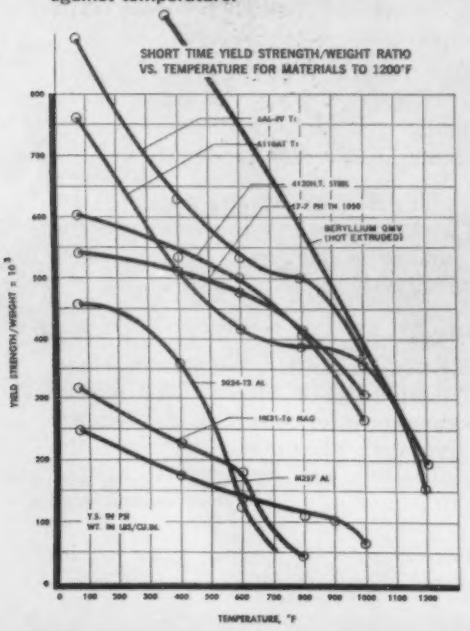
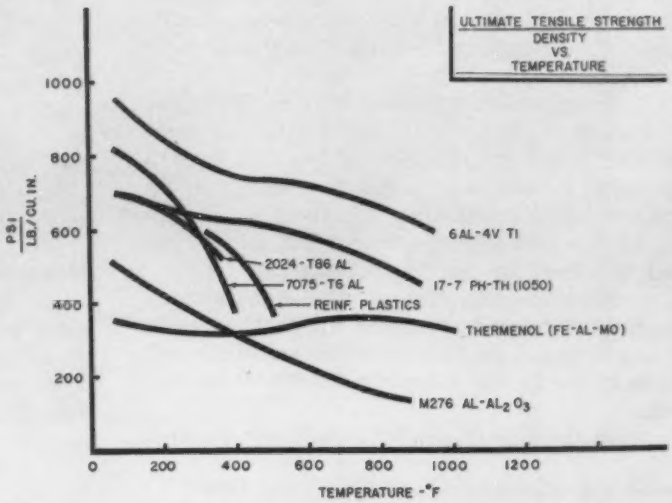


Fig. 4. Ultimate tensile strengths of various alloys being used in aircraft and missile manufacturing are plotted against temperature.



now becoming increasingly available in sheet form for airframe structures. Its retention of strength properties at temperatures up to 1000°F, and a corresponding high strength-to-weight ratio have made it an attractive material. New, higher strength titanium alloys are still under evaluation.

It has been disappointing that, despite a melting point of about 3000°F, the strength values of titanium alloys deteriorate to unacceptable levels as low as 1200°F. However, the short operating times associated with missiles and rockets offer the possibilities of taking advantage of heat-treatments and aging reactions which produce high-strength characteristics, but which decay upon long-time exposures due to metallurgical instabilities.

High-Strength Steels

The continuously-increasing temperature requirements of high-speed aerial vehicles have led to a renaissance of steel for airframe and related applications. For many of the advanced supersonic aircraft, missiles and rockets now under development or construction, most of the structural materials involve one of the six following classes of steels:

- Hot-work die or tool steels.
- Martensitic stainless steels of the 400 series.
- Low-alloy steels—such as modified 4340.
- Transformation and precipitation hardening semi-austenitic stainless steels.

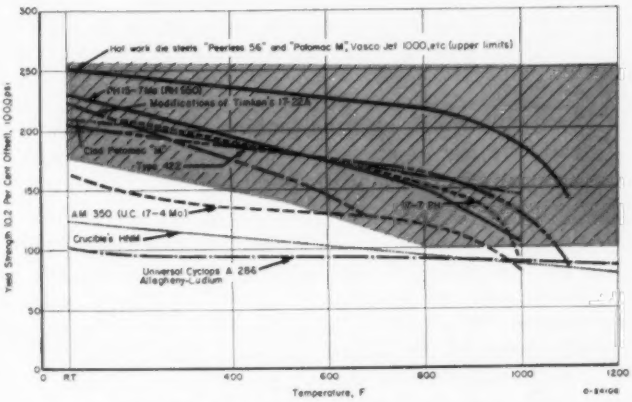


Fig. 7. Comparison of typical yield strength of presently available high-strength steels meeting aircraft and missile requirements. Tint area shows present target requirements.

- Cold-worked austenitic steels.
- Precipitation - hardenable austenitic steels.

The continuously-increasing temperature creasing tensile strengths in the range of room temperature to 800°F. Representative compositions are given in Table II and typical strength properties over a broad temperature range are shown in Fig. 7. Two major categories of developments are first, large-section, high tensile-strength, room-temperature properties of steels

continued on next page

Table II. Composition of High-Strength Steel for Airframe.

Steel	Composition, percentage							
	C	Mn	Si	Ni	Cr	Mo	V	Other
Martensitic low-alloy steels:								
1722-A	0.45	0.50	0.65	—	1.25	.50	0.25	—
17-22AS (Timken)	0.30	0.50	0.65	—	1.25	.50	0.25	—
17-22AV (Timken)	0.28	0.75	0.65	—	1.25	.50	0.85	—
Martensitic stainless steels:								
Type 418 Special (Allegheny-Ludlum)	0.17	0.50 max	0.50 max	2.00	13.0	0.50 max	—	3.00W
Type 422 (Crucible)	0.22	0.65	0.35	0.70	12.0	1.00	0.25	1.00W
Type 422M (Crucible)	0.28	0.85	0.25	0.20	12.0	2.25	0.50	1.70W
12MoV (U.S.S.)	0.25	0.50	0.50	0.70	12.0	1.0	0.30	—
Hot-work die steels:								
"Peerless 56" (Crucible)	0.40	0.55	1.00	—	3.25	2.80	0.35	—
"Potomac 2x4¾" M" (Allegheny Ludlum)	0.35	0.35	1.10	—	5.25	1.25	—	0.45W
"Halmo" (Crucible)	0.35	0.28	0.72	—	5.16	5.14	0.66	—
"Vasco Jet 1000" (Vanadium Alloys)	0.40	0.30	0.90	—	5.00	1.30	0.45	—
"Thermold J" (Universal-Cyclops)	0.50	0.35	1.10	1.40	5.00	1.30	1.00	—
Precipitation-hardening semiaustenitic Stainless steels:								
PH 15-7 Mo (Armco)	0.09 max	1.00 max	1.00 max	7.00	15.00	2.50	—	1.10 Al
17-7 PH (Armco)	0.07	0.06	0.40	7.20	17.10	—	—	1.20 Al
AM 350 (Allegheny Ludlum)	0.10	0.90	0.40	4.20	17.0	2.75	—	0.10 N
17-4 Mo (Universal-Cyclops)	0.10	0.90	0.40	4.20	17.0	2.75	—	0.10 N
AM 355 (Allegheny Ludlum)	0.13	0.95	0.50 max	4.35	15.50	2.75	—	0.10 N
Precipitation-hardening austenitic Stainless steels:								
HNM (Crucible)	0.30	3.50	0.50	9.50	18.50	—	—	0.25 P
A-286 (Allegheny Ludlum and Universal Cyclops	0.50	1.35	0.95	26.0	15.5	1.25	0.30	0.20 Al 2.00 Ti

for applications such as landing gears; and second, the use of sheet and other flat-rolled products for airframes at temperatures up to 1000°F.

In the first category, vanadium-modified 4340 compositions in the quenched and tempered conditions are being used for highly-stressed parts such as landing gears, bolting steels, and engine attack-structures. Steels with tensile strengths of 260,000 to 280,000 psi are already in use in fairly large section sizes, and it is anticipated that even higher strengths will become available by controlled composition, heat-treatments and fabricating procedures. In fact, reports of newly-developed steels exhibiting strength properties of 350,000-500,000 psi, and making use of controlled features of metallurgical structure are beginning to appear. Since such high tensile strengths involve relatively low tempering temperatures (400-800°F) it is not surprising to find a large decrease in strength properties at higher temperatures for sustained exposure periods. But for short-time applications, sufficient strength is retained even at temperatures as high as 1200°F.

The second category involving rolled-sheet products for use up to 1200°F currently is receiving much attention.

The hot-work die-steels (based on the 5 per cent Cr composition) exhibit the highest strength-to-weight ratio between 400-1000°F of any commercial structural metal. They have excellent ductility over a wide temperature-range, are not particularly notch sensitive, and even when clad with austenitic stainless steel, to provide corrosion and oxidation resistance still exhibit impressive strength characteristics.

While the 400 type martensitic stainless steels (containing about 12 per cent Cr) can be heat treated to high strengths, it appears doubtful that present grades will have wide application for skins and related aircraft applications. The problems of critical tempering temperatures, susceptibility to hydrogen-embrittlement and stress-corrosion cracking, and composition sensitivity appear to be limiting factors. The 400 series steels have received extensive usage for turbine-compressor materials. Since new types of martensitic materials are now under development, improvements may be anticipated.

The precipitation-hardened, semi-austenitic stainless steels have been termed the "work horse" of the aircraft industry. The two best known chromium-nickel steels in this class are the 17-7 Ph and AM350 containing 1 per cent aluminum and 3 per cent molybdenum respectively. PH 15-7 Mo and 17-4 PH have also shown some recent possibilities. High-strength properties in the order of 225,000 psi can be achieved in these steels by taking advantage of the martensite transformation as well as by subsequent precipitation reactions. These steels have interesting high-temperature properties, good corrosion resistance, and can be easily fabricated. Heat treatment can be accomplished after forming. The major disadvantages appear to be a tendency toward embrittlement with time, between 600 to 800°F, and low ductility.

For the fully-austenitic stainless steels, two different approaches are being employed to gain desired properties. Age-hardened austenitic stainless steels which involve the precipitation of carbides, (e.g.) vanadium carbide, show superiority to the other martensitic and semi-austenitic varieties above 1000°F. Their room and intermediate-temperature tensile properties are much lower, which is their chief disadvantage, but the

Continued on page 38

Fig. 6. Ultimate tensile strength per 16 lb per cu in. is plotted against temperature.

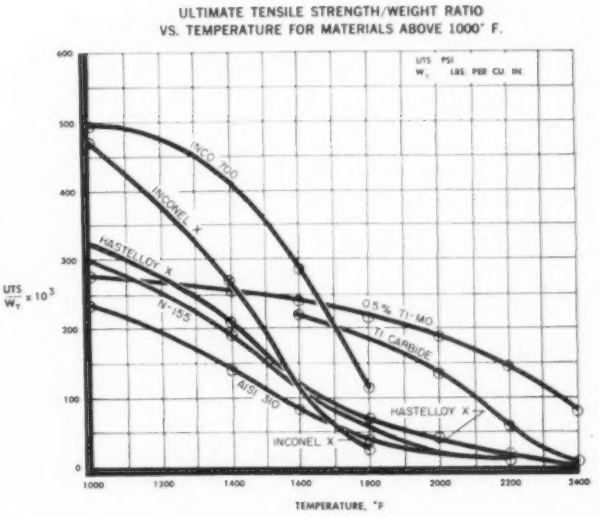


Fig. 5. Moduli of elasticity of various alloys being used in aircraft and missile manufacturing are plotted against temperature.

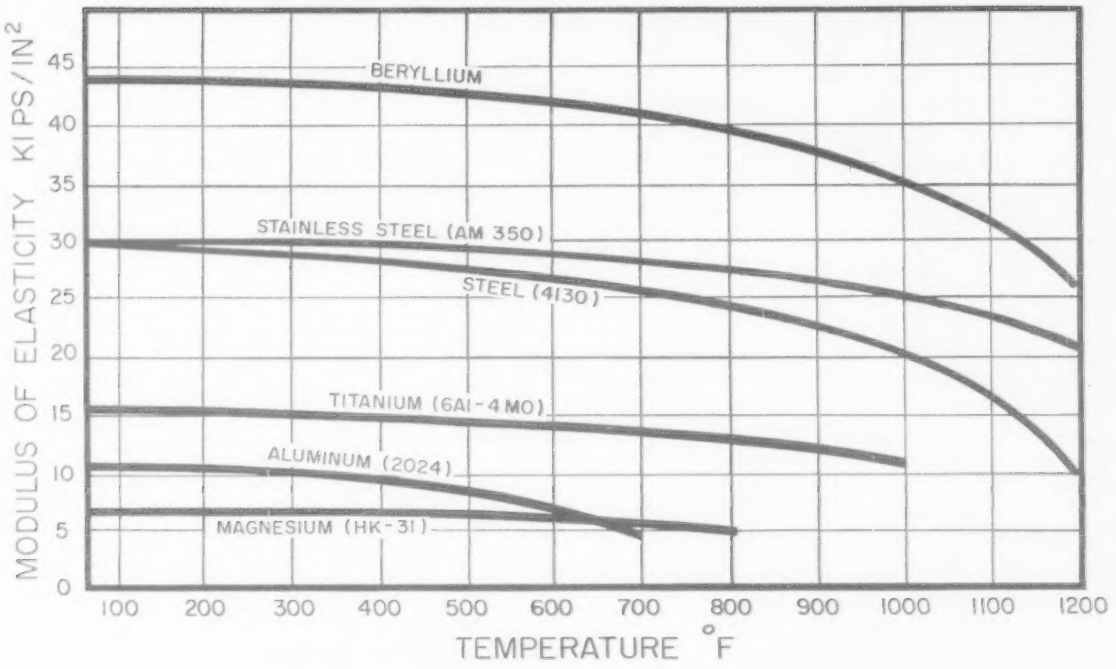


Table I. Temperature Range of Usage for Classes of Aircraft and Missile Materials.

Alloy Family	Useful Temperature Range
Aluminum alloys	RT to 500°F
Magnesium alloys	400°F to 800°F
Alloy steels	RT to 1200°F
Titanium alloys	500°F to 1100°F
Stainless Steels	RT to 2200°F (for oxidation resistance)
Age Hardenable Stainless Steels	RT to 1000°F
High Temperature alloys	1000°F to 2100°F
Molybdenum alloys	1600°F to 2500°F

Table V. Refractory Metals.

	Refractory Metals		
	Melting Point (° F)	Density (g/cc)	Modulus of Elasticity (psi)
Tungsten	6170	19.3	50 x 10^6
Rhenium	5740	20.0	42 x 10^6
Tantalum	5425	16.6	27 x 10^6
Osmium	4900	22.5	80 x 10^6
Molybdenum	4760	10.2	45 x 10^6
Iridium	4450	22.5	75 x 10^6
Columbium	4380	8.57	13 x 10^6
Chromium	3430	7.19	36 x 10^6
Zirconium	3380	6.5	14 x 10^6
Titanium	3140	4.5	15 x 10^6
Vanadium	3125	6.11	21–22.5 x 10^6
Hafnium	3100	11.4	20 x 10^6

Table IV. Titanium Sheet Rolling Data.

	Properties in Solution Treated Condition				Short Time Properties in Heat Treated Condition					
	Room Temperature				Room Temperature			800° F		
	UTS KSI	YS KSI	Elong % in 2″	Bend Duct*	UTS KSI	YS KSI	Elong % in 2″	UTS KSI	YS KSI	Elong % in 2″
Target Props.**	120	—	15	2T	180	160	10	130	105	15
Selected Alloys:										
3 Al-6 Mo***	135	—	15	2.5T	180	160	7	130	105	15
4½ Al-3 Mo-1V***	150	125	15	3T	170	150	10	100	80	15
6 Al-4V***	130	120	10	6T	170	155	7	100	80	—
2½ Al-15V***	100	—	15	2T	180	160	6	130	105	10

* Minimum 105° bend without cracking with radius of bend expressed as multiples of the thickness of the sheet.
** These properties were specified on the basis of information furnished by the airframe industry.
*** Hydrogen shall not exceed 150 parts per million.

rate of decrease of properties within the range of 800 to 1200°F is not sharp. They have the best creep-resistance within this range of all the high-strength steels and also exhibit superior ductility.

Cold-working, prior to aging, of these alloys increases the degree of aging and can provide a phenomenal increase in strength, of course, with decreasing ductility. New alloy compositions in this class of steels are under development with possibilities of achieving over 200,000 psi room-temperature tensile-strength and 120,000 psi at 1200°F.

Cold-rolled austenitic stainless steels, (e.g.) AISI 300 series, long have been used for numerous aircraft applications where high strength, corrosion resistance and weldability are necessary. They have tensile properties ranging from 180,000 to 290,000 psi at room temperature, retain their strength properties quite well up to 1000°F, and are of particular interest for missile construction, (e.g.) skin applications. These steels exhibit low ductility and directional properties.

Thermenol

Another ferrous alloy which is receiving attention for structural-sheet applications and compressor blading is Thermenol, an iron-base alloy containing primarily 16 per cent Al and 4 per cent Mo. The excellent oxidation-resistance of the iron-aluminum alloys has long been recognized, but the brittle behavior of compositions containing more than about 8 per cent aluminum is only now beginning to be overcome with new fabrication techniques.

Thermenol contains no strategic materials, has outstanding oxidation-resistance, good corrosion resistance, good strength properties up to 1000°F, and even in its preliminary state of development exhibits high-temperature properties comparable to stainless steels with a 15 per cent lower density. The alloy is weldable but warm-forming must be performed because of its marginal ductility. The potential of this alloys system is yet to be fully exploited. See Fig. 4 and Table 6.

Beryllium

The increasing requirements of aerial and space vehicles for lightness, thinness, buckling resistance, and high-temperature strength properties have made beryllium one of the most intriguing metals in the current materials picture. With a density equal to that of magnesium, a melting point twice that of aluminum (and only slightly lower than that of steels) and a modulus of elasticity 1.5 times greater than that of steel, the weight savings and increased stiffness potentialities are interesting. The superiority of

Table III. Properties of Beryllium.

Physical Properties:					
Density, lbs/cu in	0.066				
Melting Point, °F	2340				
Thermal Conductivity, BTU/hr/sq ft/ft/°F:					
70°F	87				
1200°F	85				
Coefficient of Expansion, per °F:					
70°F	6.4×10^{-6}				
1200°F	12.4×10^{-6}				
Specific Heat, BTU/lb/°F:					
70°F	0.46				
1200°F	0.67				
Modulus of Elasticity, psi:					
70°F	44×10^6				
600°F	43×10^6				
1200°F	26×10^6				
Typical Mechanical Properties:	70°F	400°F	600°F	800°F	1200°F
Tensiles Strength (1000 psi)	125	—	85	—	31
Yield Strength (1000 psi) 0.2% offset	95	—	65	—	20
Elongation %	1-5	8-16	—	16-34	10-14

Table VI. Properties of Extruded Thermenol.

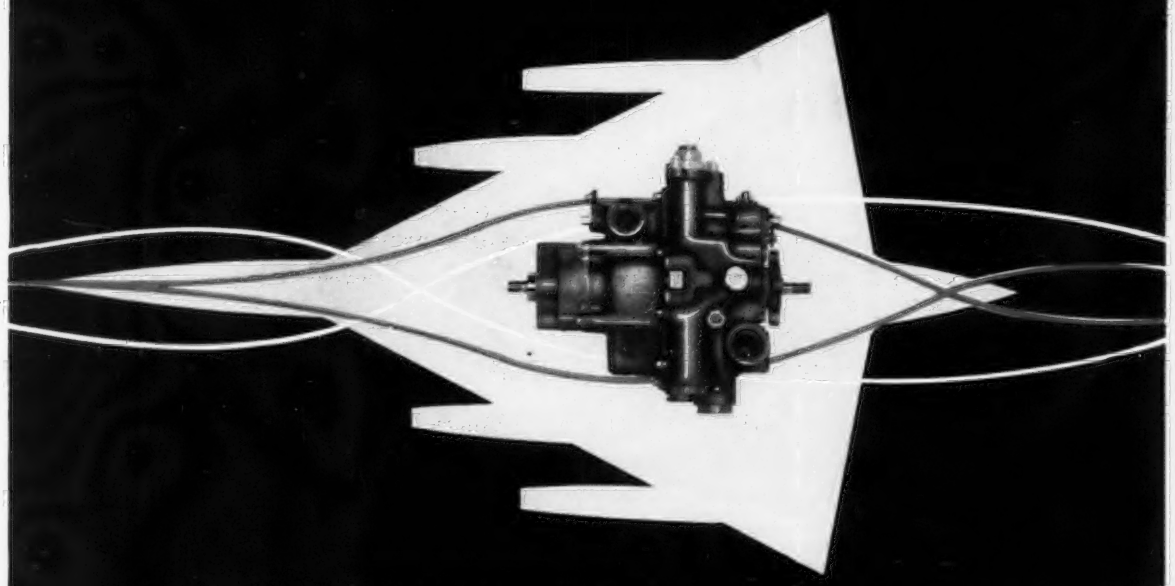
Temperature (°F)	Tensile Strength (psi)	(0.2) Yield Strength (psi)	% Elongation	% R.A.
Rm. Temp.	82,900	66,800	1.9	3.8
500	77,800	45,900	3.3	6.1
600	81,100	43,400	4.4	8.1
800	84,700	45,000	6.8	10.1
1000	77,200	55,500	37.3	79.5
1200	47,900	30,200	54.2	91.0

beryllium with respect to the modulus of elasticity and strength-to-weight capabilities is shown in accompanying data. Beryllium currently is fabricated by powder-metallurgy techniques involving hot extrusion or hot pressing of powders. Extrusion results in much higher strengths, but the properties, in general, are quite sensitive to fabrication procedures.

Despite its obvious superiority in properties (Table 3), a number of serious problems and disadvantages must be overcome to realize the full potentialities of this metal system. The lack of ductility (brittleness), toxicity, questionable availability and high cost have for many years led to its disregard as a structual engineering material.

Its brittleness is a major deterrent. Transverse-ductility and notch-sensitivity need to be significantly improved. There is still a serious question as to whether its brittleness is an inherent feature (resulting from its crystallographic structure) or is due to impurities.

unique control problem solved



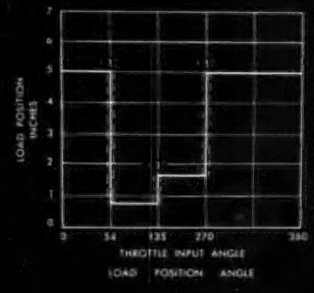
The Waldorf Instrument Company's Fluid Systems Division recently undertook research and development activity on a unique control problem for aircraft gas-turbine engines. It was required that a hydraulic unit be supplied which would provide the specified in-put vs. load position schedule and incorporate fuel interlock and over-ride mechanisms.

A component package was designed which housed the following elements:

- HYDRAULIC SERVO VALVE
- ROTARY POSITION SUMMING MECHANISM
- HYDRAULIC STEP INPUT
- FUEL INTERLOCK VALVE
- AUTOMATIC FUEL PRESSURE OVER-RIDE
- FEEDBACK LOADING MECHANISM

The control meets all requirements of military specification MIL-E-5009A.
This unit is designed to operate in an ambient temperature of —65° F. to 475° F. with servo oil temperatures of —65° F. to 425° F. at 3000 psi.

For further information, contact —



waldorf

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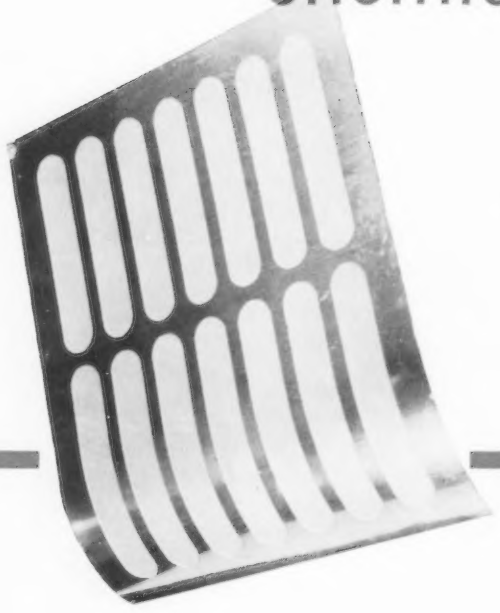
chemical milling



has achieved industry status by growing from a mere weight-saving process to an economical way of etching intricate shapes; still no machining panacea

by **Lew B. Stearns**, chief engineer
United States Chemical Milling Corp.
and **John P. Kushnerick**

Two of the major problems in aircraft and missile manufacturing are: the development of materials and structures capable of withstanding the tremendous forces and temperatures of supersonic flight; and the production of maximum strength components from minimum thicknesses and minimum weights of these materials.

One of the more outstanding new techniques developed to meet the demands of maximum strength coupled with minimum weight is the chemical-milling process, hailed in some quarters as the only new production-milling technique since the invention of machine tools.

Actually the process is not new; rather what is being done with it is different. For many years photoengravers have used much the same process in preparing zinc and copper engravings to produce photographs for newsprint.

The process is basically a controlled chemical decomposition, or chemical removal of metal; it is also replacing mechanical milling or machining operations for many intricate airframe components. The amount of metal removal or depth of cut is controlled by the length of time the part is immersed in the milling solution. Location of the milled areas on a component is controlled by masking certain areas from the milling solution.

Chemical milling has grown, in three years, from a mere weight-reducing process on mechanically-milled parts, to the point where it is the most feasible answer to shaping many complicated parts.

How Parts Are Chemically Milled

There are four steps in the milling of most materials:

- Cleaning
- Masking
- Etching (milling)
- Demasking

CLEANING usually consists of solvent-wipe and vapor-degrease, hot alkaline dip (except aluminum), water rinse, and dry. A clean surface is essential to assure uniform adhesion of the maskant.

MASKING is accomplished by dipping, spraying, or roller-coating. Part size and configuration determine the technique.

The type of masking material used is governed by the material being etched. A particular neoprene maskant has been used with some varying amount of success on steel, titanium, magnesium, and aluminum, and certain alloys of these metals. However, specific maskants seem to give better results with each specific etchant (i.e. vinyls with acid).

Patterns are located on the masked part by placing a designed template on the part after it has been oven-cured. The template shape is traced

Large, outdoor facilities at United States Chemical Milling Corp. represents one of the most complete, versatile tank lines in this country.

with a sharp cutting instrument, and the maskant is stripped manually from the areas to be chemically-milled (etched).

ETCHING is accomplished by immersing the part in an agitated etching solution. The depth of the etch is governed by the immersion time. Parts are rotated during the etching cycle to insure uniform etching and fillet radii. Etching rates can vary as much as 0.0001 in./min to 0.010 in./min; most etching solutions are compounded for the 0.0001 in./min rate.

DEMASKING is accomplished manually or chemically. Most chemical demaskants work on a bond-release mechanism. The maskant itself is not dissolved, the metal-to-maskant bond is destroyed, and the maskant can then be flushed off with water pressure or peeled manually.

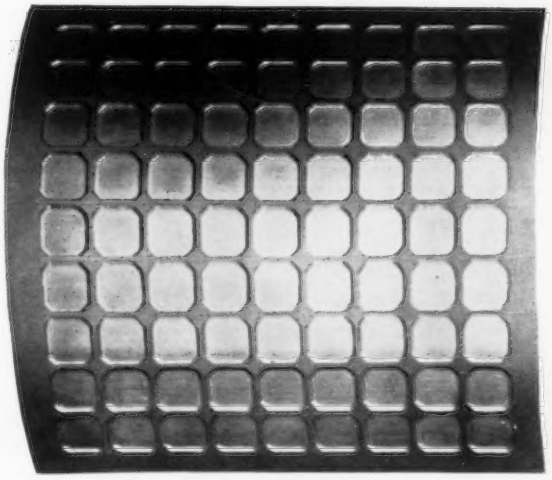
The part is then lowered into a quenching tank to insure that the chemical action is stopped. A coat of smut forms on most parts; it can be removed by a short dip in a brightening solution.

Advantages and Desirable Results

There are two outstanding advantages of chemical milling and several desirable results.

The first advantage is the ability to mill parts after they are formed, attempts at complex machining after forming are time consuming and hence costly. The second advantage is that large quantities of parts can be milled simultaneously.

Complex waffle-pattern is chemically milled in curved skin section without much difficulty.



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chemical milling

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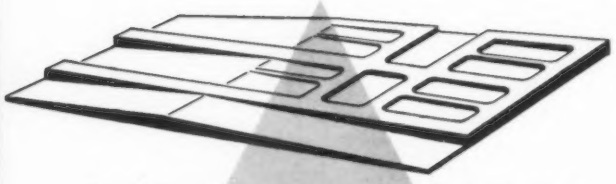
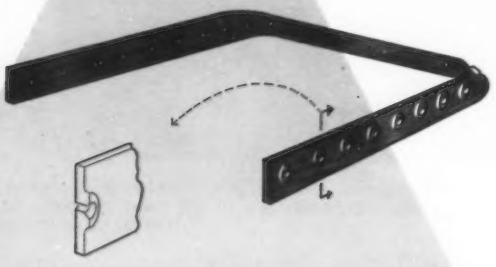
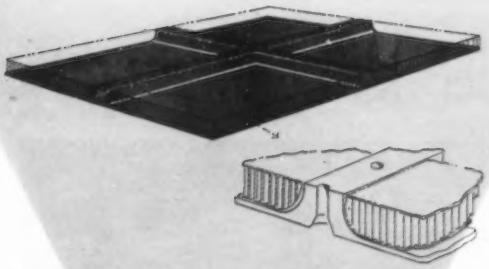


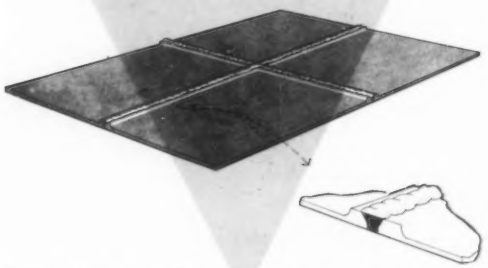
One of the most complicated sections to be chemically milled required nine steps to give reverse taper and waffle design.



Heavier lands give extra strength at attachment points on chemically-milled canopy frame.



Lands are also left on sandwich skins to provide good attachment points. This eliminates secondary-bonding processes.



Butt-welding is facilitated in thin-gauge sheet by leaving an extra edge-thickness during chemical milling.

Most machines can produce only one part at a time.

The several desirable results of chemical milling are:

- Physical properties do not seem to be impaired.
- There is no evidence of intergranular attack or change in surface composition.
- Corrosion resistance is not impaired.
- Surface does not usually require any further finishing.

Areas of Application

WEIGHT REDUCTION was the area in which chemical milling found its first application. Forming operations rather than optimum design criteria often dictate the thickness of a part. This may happen when a section is cast, extruded, forged, or press-formed. In order to have the material flow properly during the forming process, it may be necessary to use thicker sections than are required to carry the structural loads. As an example, the IRBM missile skin illustrated is extruded and stretch-press formed. The I-section stiffeners are extruded from the original plate-stock. After extrusion, stretch-forming is used to produce the curvature. To eliminate the many pounds of aluminum needed for strength in the stretch-forming operation, the final part is chemically milled. Eight sections form the missile hull, with a weight saving of 10 lbs in each section.

GAUGE REDUCTION is sometimes a problem for designers who are forced to select materials in standard gauges. Chemical milling provides a means of producing skins and panels of any thickness. The same can be done with metal tubing. In this instance, removal of excess metal by machine is extremely costly. Frequently, when reducing standard-gauge material to non-standard gauges by means of chemical milling, lands of the original material thickness are left where fasteners are to be used. This permits countersinking. A thin panel must usually be dimpled if the fasteners are to be flush with the surface, these lands increase the tear-resistance of the panels in the area of the fastener.

An example of the benefits that may be obtained from chemical milling is the canopy frame illustrated. After the frame was originally designed, its thickness had to be increased because of difficulties experienced during forming. Chemical milling was used to reduce the thickness after forming. However, the section was redesigned in order to take better advantage of chemical milling. An integral stiffener was designed into the section, permitting further reductions in thickness. At each point of attachment, a chemically-milled land was provided to increase the strength of the section in the areas of attachment.

TAPERING has been accomplished on sections up to 50 ft long. This is done by gradually raising and lowering the part in the etching solution. The bottom end of the part enters the solution first on lowering, and leaves last on raising—in this way it is in the etching solution longest, and receives the deeper etch resulting in a taper. It is extremely difficult to stop the taper at a specific point, so the tapering is carried beyond the point desired and cut off.

Tapering parts with complicated cross-sections similar to the one illustrated has been done with great success. The ability to taper complicated parts opened new horizons for designers.

INTEGRAL STIFFENERS, produced by chemical milling, are finding growing applications in the aircraft and missile industry. A section with integral stiffeners is believed stronger than a section with stiffeners attached by bonding or riveting, since load is transferred uniformly instead of being concentrated at the attaching points.

SUBSTITUTION for spot welding and metal bonding is another increasing application for magnesium parts. This is accomplished by using the intricate shaping possible with chemical milling instead of attaching various separately-formed parts to effect a final shape. The number of parts rejected was lowered in one instance, as was the cost of producing each unit.

Fabrication Simplification

It is difficult to compare chemical milling and machine milling on an equal basis because chemical milling does not generally compete with machining operations. Chemical milling is used when machine milling is either impossible or too costly. Furthermore, a chemically-milled part often has features that are impossible to include on a machined part.

For example, where a rivet must be flush-mounted on a thin skin, the surface of the skin is dimpled. Dimpling has been avoided conventionally because it tends to stretch and "oil can" the skin. This is particularly undesirable in sandwich constructions. Dimpling after forming tends to alter the skin so that a perfect mating between the skin and the honeycomb is almost impossible. This mating is very critical in sandwich construction.

A more satisfactory method is to chemically-mill the skins, leaving lands in the areas of attachments. There is then sufficient metal to countersink the fastener. In addition, the point of attachment is stronger in that there is additional material.

Somewhat the same technique is used in riveting very thin skins to stiffeners. In the case of a thin skin, the edge fastener is more critical than the skin. That is, any failures will tend

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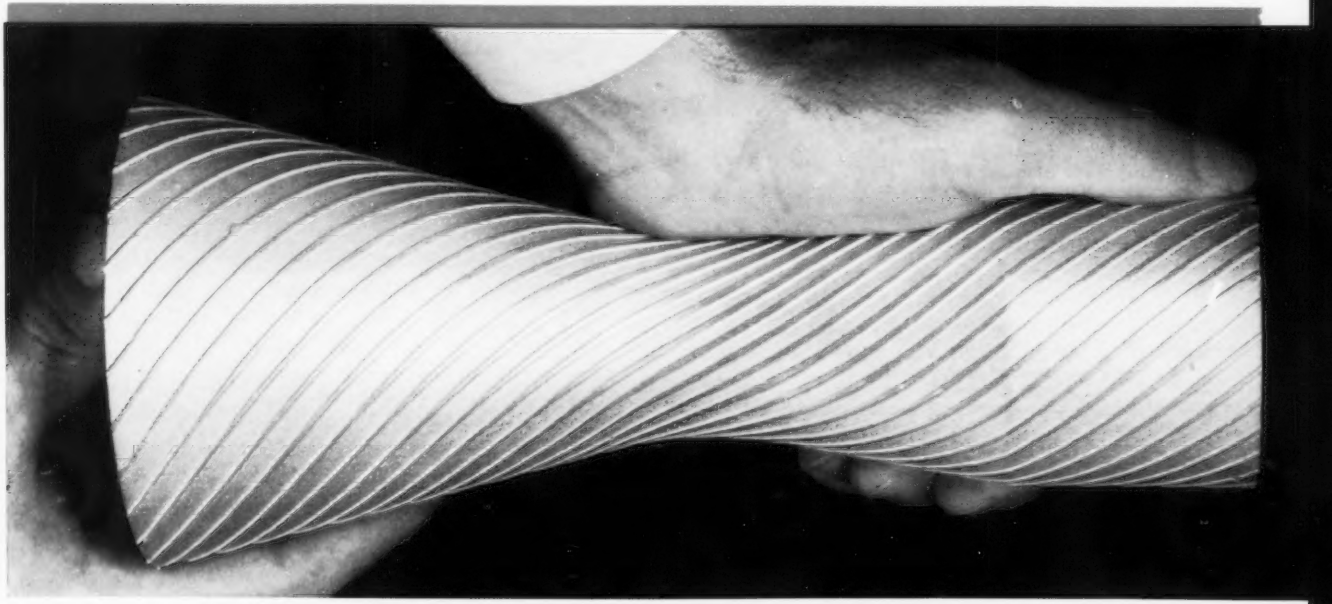
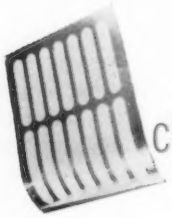


Intricately fluted rocket-engine case was made by chemical milling. Flutes are used to circulate liquid propellant as a cooling medium for rocket motor.



chemical milling

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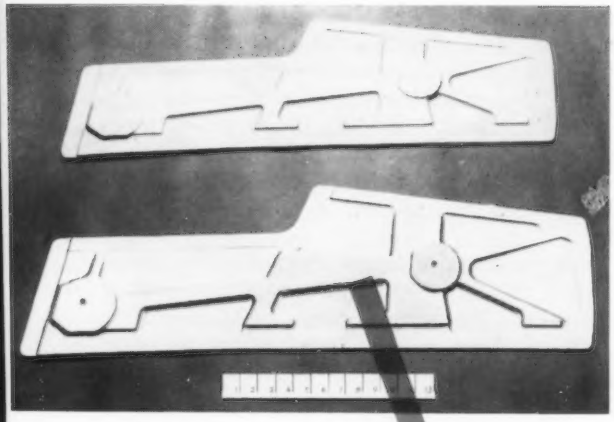
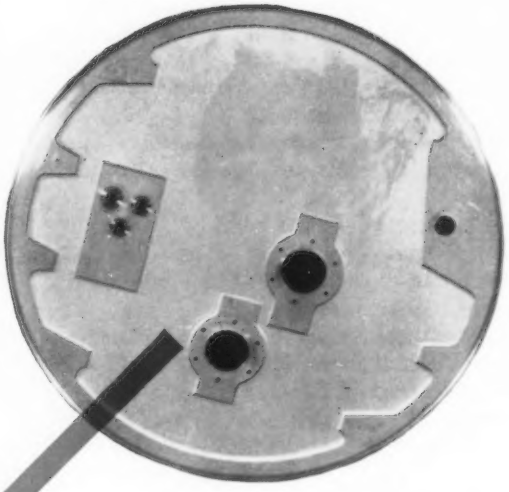
IRBM skin sections are extruded and stretch-formed into a 45-deg arc. Ten pounds of weight penalty is then removed by chemical milling each section, resulting in a weight saving of 80 lb/missile.



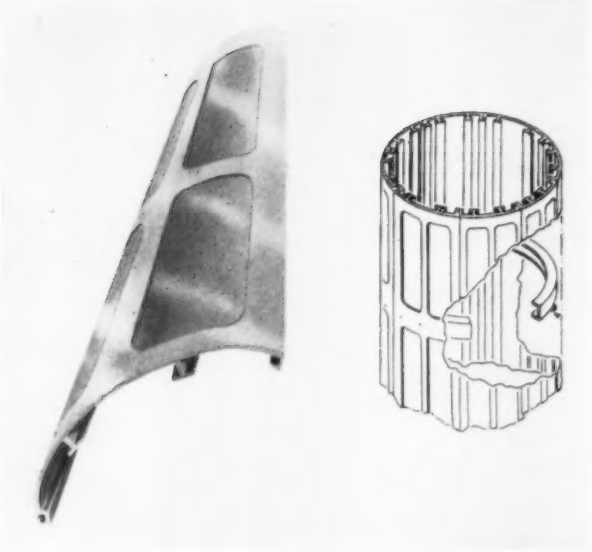


Forging shown at top was reduced in weight considerably by chemically milling web areas from 0.200-in. to 0.093 in. thickness

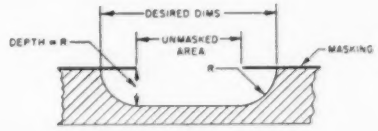
Machining time and weight saving were effected in this Snark bulkhead by using chemical milling. Tolerances greater than 0.002 in. are not to be expected.

Light weight and integral stiffening is assured in missile nose-cone by removing excess metal.

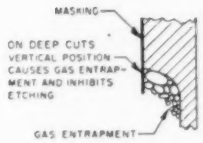
Airscoop for North American F-100 series fighters is milled to waffle patterns with chemicals. "Dishing" is an undesirable effect in etching some metals; i.e. magnesium.

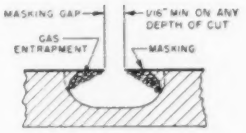


TYPICAL ETCHING CHARACTERISTICS



A – GOOD ETCHING





SMALL OPENING FOR RELATIVELY DEEP ETCH RESULTS IN GAS ENTRAPMENT AND ROUGH ETCHING

to occur in the immediate region of the fastener. In order to eliminate this problem, either two rows of fasteners must be used, or the skin can be made of double-thickness material. However, by using a thick panel and then chemically milling it to proper thickness, one row of rivets can be used. Lands are left in the areas of attachment, providing the increased strength that is needed.

For certain applications welded skins have become more popular since the introduction of chemical milling. During World War II, the advantages of welded construction over riveted construction were demonstrated in ship yards, and these advantages still apply to many fabrications. However, in order to use welded panels with butt joints, a certain minimum thickness is required. When aircraft and missile skins are too thin for welded joints, thick sheet-stock is chemically milled to the desired thickness and raised lands are left at the edges of the panel. In this way, adequate material is left for a butt-weld without the penalty of a heavier skin.

Limitations and Disadvantages

The depth of cut practical with chemical milling is about ½ in. maximum. The radius of the fillet is approximately equal to the depth of the cut, thus with a 1-in. cut, there would be a fillet radius of 1 in., this would represent a significant increase in weight when compared to a machined part.

For certain materials, surface irregularities in the base stock are also reproduced in the etched part. This is especially true with magnesium. There is no detectable magnification of surface irregularities. In some instances with aluminum, surface imperfections have been removed with chemical milling.

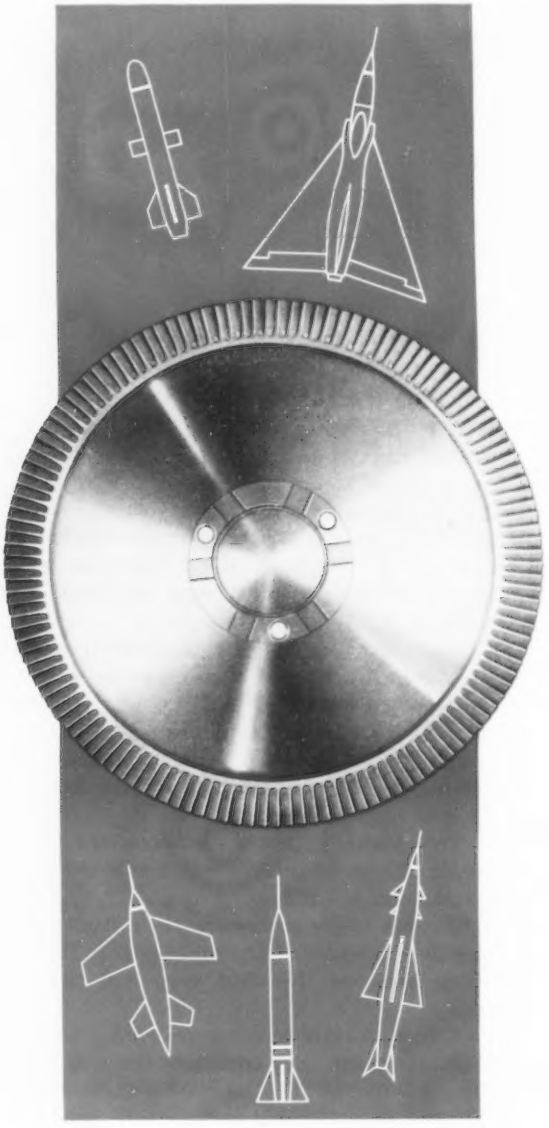
Tolerances in some instances are not as exacting as those obtainable with machined parts; i.e. magnesium ±0.002 in.

Welded areas and assemblies require special handling because of the difference in the rate of attack between the weld area and the base material.

Although etching rates are rather uniform on steel, aluminum, and titanium, there is a phenomenon known as "dishing" which occurs with magnesium. If the center of an etched area were to be held to a minimum of 0.045 in., it may have to have 0.055 in. on the edges. There are some expensive heated and refrigerated etching processes to combat this.

Etching of very small-width cuts, or the ID of most common tubing is not possible with any degree of accuracy because of the gassing effect of the etchant illustrated.

somewhere . . .
this turbine rotor wheel
is making history



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Circle 14 on Inquiry Card, page 65

Fairey Rotodyne

40-passenger VTOL craft combines advantages of fixed-wing, helicopter, and autogyro configurations

by Ronald A. Cole

To appreciably increase the speeds of helicopters, it is necessary to resort to higher rotor speeds than presently used, in order to insure that the inner portion of the retreating blade does not stall. This, however, is not easily practicable because of power requirements, compressibility effects on the advancing blade tip, and increased structural loadings. Fairey has compromised these conflicting requirements in designing the Rotodyne by using a power-driven rotor for direct lift only. Once airborne at sufficient altitude, up to 60 per cent of the lift is progressively transferred to a partial wing, till cruising speed is reached. The remaining required lift is provided by the windmilling rotor which is then only lightly loaded, hence capable of being flown at high speeds without danger of stalling. Such a method calls for a technically advanced machine, but its complexity is no greater than that of a multi-engined helicopter of a twin rotor configuration.

Studies showed that the pressure-jet driven rotor was best for this application on account of its lightness, its minimum drag during autorotation, and it did not need torque compensation. Fuel requirements for tip-mounted rockets would have been too great, and athodyds (ram-jets) at subsonic speeds would have been uneconomical to say nothing of their high drag, when not used.

Pressure-Jet Air Supply

In the present design, air is supplied to the rotor-tip mounted pressure-jets by two auxiliary compressors mounted one behind each main turbo-prop engine. These are driven by the turbine via an extension shaft and a hydraulic clutch.

Rotor pylon structure features tubular framework and stiffened-skin envelope with access panels.

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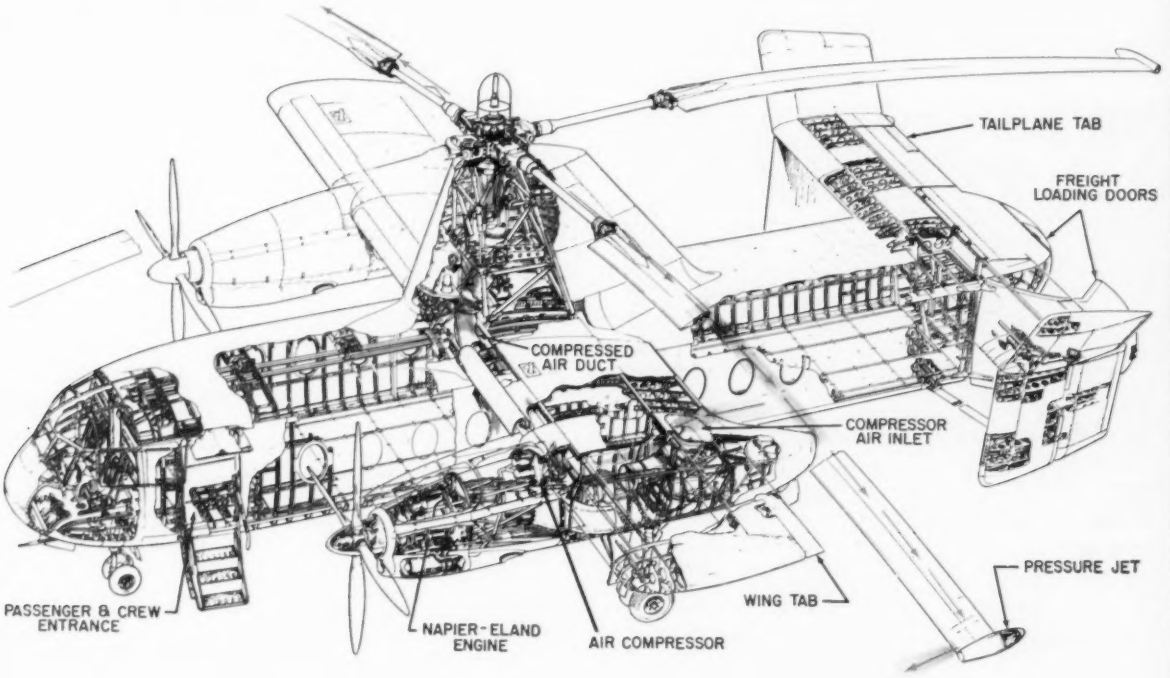
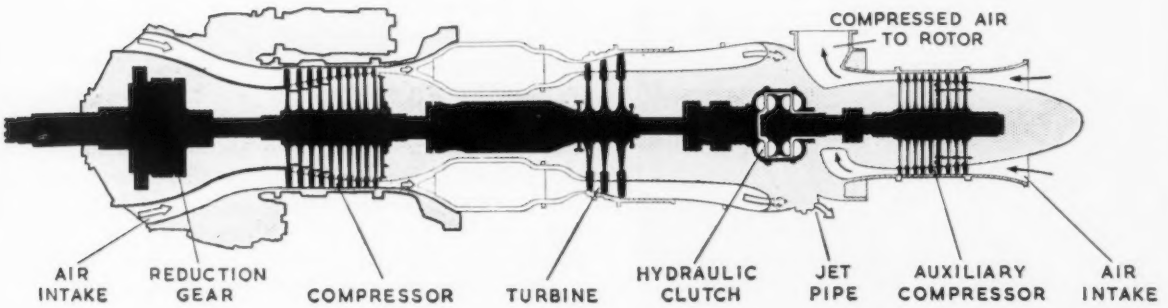


FAIREY ROTODYNE SPECIFICATIONS

Accommodation	40 to 48 passengers
Range	up to 430 mi
Cruise Speed	170 to 180 mi/hr
Rate of Climb (sea level)	1670 ft/min
Weight	39,000 lb
Tare Weight	24,030 lb
Payload	7400 lb
Wing Gross Area	475 sq ft
Wing Span	46½ ft
Fuselage Length	58 ft, 8 in.

Fuselage Interior Size	6 x 8 x 46 ft
Rotor Diameter	90 ft
Rotor Blade Chord	27 in.
Rotor Disc Loading	6.14 lb/sq ft
Rotor Tip Speed	720 ft/sec
Powerplants	two 3500-ehp Napier Eland
Sea-Level Take-Off rpm	12,500
Specific Fuel Consumption	0.595 lb/ehp-hr
Fuel	JP-1 MIL-F-5616 or JP-4 MIL-F-5624 C



Fairey Rotodyne

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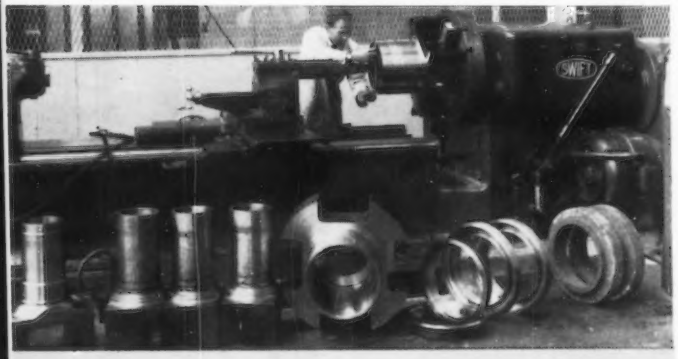
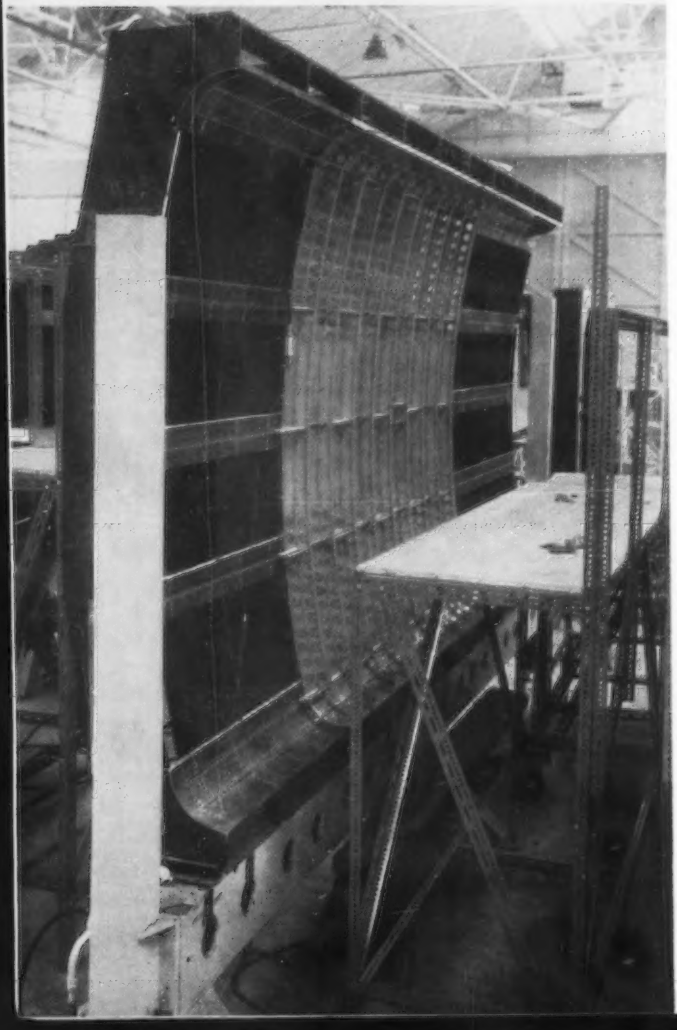


Massive rotor-hub components are machined from stainless-steel forgings.

Envelope jig used for the assembly of fuselage panels.



Air to the compressors is taken from intakes on the topside of the wing; this arrangement takes advantage of the rotor downwash. Intake air is then pumped along ducting in the wing leading edges, and up the pylon. At the top of the pylon the two ducts merge into a distributor which insures that air from either compressor serves only two opposing rotor blades. Thus, in the event of a main engine or compressor failure, the efficiency of two out of the four units is not impaired, and by increasing the fuel-to-air ratio in the two working jets, power may be somewhat recovered. This is an important safety feature because not all the available turbine-power can be expended on pumping air; some of this power has to be held in reserve to provide directional control at low speeds. Figures have been quoted crediting the Rotodyne with a climb of 150 ft/min at 5000 ft, using one engine at cruising power only. More than anything else, this detail shows how the designers have obtained safety characteristics comparable to those of conventional twin-engine airliners. Furthermore, it is anticipated that autorotational descent, even in the event of complete power failure, at zero forward speed, should result in a safe landing.

Because air is supplied to the jets under a compression-ratio of about 6 to 1, and temperatures in the region of 250° C (482° F) are obtained, special emphasis has been placed on sealing devices. To this end, carbon seals running on case hardened steels, and metal-to-metal sealing in the form of piston rings are used. Also, provisions for expansion were made through the use of elbows and sliding joints. Tip drive combined with blade-shank resilience eliminated the need for drag hinges. In turn, this reduced vibration levels and simplified the fatigue problem. Much importance has been placed on this latter problem, and stress levels have been kept low enough to provide long service life. The rotor-hub control assembly is suspended on a universal joint with an arrangement that allows differential blade flapping only while control movements take place.

High centrifugal forces in the rotor system made it important to control fuel flow from the fuselage and not the rotor tip. However, these same forces still act on the fuel once it leaves the restrictor-distributor on the rotor-head. Therefore, special consideration was given to the choice and positioning of pipe runs in the rotor. Pressures of 3000 psi can be obtained by centrifugal pumping action alone. Yet, internal friction of the pipe, and possibly cavitation, can cancel it out at the tip. It has been found that two basic parameters must be broadly satisfied for satisfactory operation: (1) at minimum speed the smallest fluel flow must give not less than 50 psi at the

sprayer, and (2) maximum flow at this slow speed should just fill the line from restrictor to sprayer. Another point is to keep the pipes as cool as possible to prevent vaporization.

Rotor Blades

Apart from the trailing edge section, blade construction is entirely of stainless steel. The blade envelope, with its relatively small leading edge radius, had to be formed from material having properties above specification figures. Firth Vickers Stainless Steels Ltd. produces a high strength grade of DTD. 166B having a minimum UTS of 143,000 psi and rolled to 20 gage. This envelope is in one piece over the airfoil span of 35 ft, extending from the rear spar at near 50 per cent chord, round the nose, then back again to the rear spar. Total blade chord is 27 in. The spar is employed to close the main torsion-box structure and consists of two 16 gage, "L" sections riveted together. Using closely-spaced countersunk-head Monel rivets, the skin is attached to the rear spar, close pitch ribs, and the leading edge spar.

Two hat-section stringers span the lower surface to stabilize the skin against compression loading when the blades are at rest. A massive leading-edge spar plays an important part in bringing the blade C.G. to a correct position at about 25 per cent chord. A major problem arose in the manufacture of this spar because no manufacturer in Europe, or the U. S. A., could supply a 35-ft long billet of steel suitable for this purpose. The reason being limitations imposed by heat-treatment equipment. Consultation with the English Steel Corp. produced a suggestion that an air-hardening steel could be used, along with resistance-heating methods, for hardening and tempering. After some adjustments of method, satisfactory billets were manufactured along these lines.

Manufacturing the Rotor Blades

Eventually, 40-ft billets, 7½ x 3¾ in., were delivered. They were split on a Wadkin Spar Miller to make two sections approximating the final shape. After being returned for heat-treatment, attachment points were machined before the whole was rough machined to taper and profile. Final profiling and polishing was done by hand, a laborious process.

Inside each blade envelope three stainless-steel tubes, each about three in. diam and 34 ft long carry compressed air to the jets. The tubes are loaded only by their own centrifugal pull; this is transferred to the hollow blade-shank through a welded, tubular fitting. To reduce stresses to a minimum it was desirable to progressively reduce their wall thickness. This was done in steps taking down from 20 to 29 gage. Flanged clearance holes are provided in the pressed-steel ribs; at alternate ribs, a Fluon self-lubricating ring locates the tubes, but allows differential straining between the tubes and the envelope.

Production wise the blades are broken down into two parts; the main load-carring portion extending aft to the rear spar, and short lengths of light, riveted trailing-edge fairing. Jigging employed for the whole air-frame was of the Fairey Patent Envelope type, wherein an envelope holding the drill bushings is laid on the skin material. The bushings and locating lugs are positioned by marking off on the inside of the envelope; a surface which is an exact replica of the structures outside face. Once the skin is formed to contour, rivet lines are located by drilling through from the jig. Parts of the internal structure are then laid upon the skin and riveted in position. This method of building from the outside in, has found favor in many British firms. It reduces jigging to a minimum, particularly during the transference of dimensions from drawings to the jigs. The need to substract odd gage thicknesses, which are generally in thousandths of on inch, from some dimensions and add them to others is obviated in many cases.

For blade manufacture, the jigs were made of fiber glass, thicker than usual because of the close pitched drilling pattern. These were "laid up" on an accurate cast-aluminum replica. To get correct alignment of the light trailing-edge assembly, an open-frame jig was used. Throughout the whole program, strict weight control has been maintained by selective assembly. Together with the jigging methods, this has resulted in complete interchangeability between all blades on the two rotors. Balancing methods are applicable to the whole rotor, and a blade changing technique has been derived which allows any blade to be changed without affecting the others.

A combustion chamber completely buried within the airfoil section would have given the lowest drag, but not the best combustion efficiency, because of the oval shape necessary to get sufficient volume. Side entry into the exterior type actually used, also penalizes combustion efficiency, but not quite to the same extent. In addition, it is easier to modify the exterior type in the light of experience, and the end-plate effect slightly reduces aerodynamic tip loss. Chamber dimensions are based upon rich-mixture working conditions since these give minimum size, mass-flow requirements and weight. They are designed to operate at a rotor tip speed of 720 ft/sec.

Development blades were made of ordinary stainless steel, as their life was not important and experimental changes could be quickly incorporated. Those used for flight are of Nimonic

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Fairey Rotodyne

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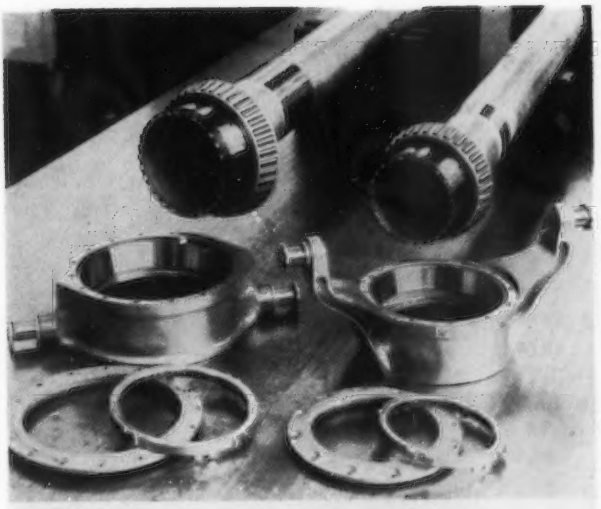


Close-up of rotor shanks with pitch bearings and their housings disassembled.

alloys which present some welding problems. To maintain strength, special welding wire had to be used, along with dc, argon-arc equipment, and post-welding heat-treatment. Since a very high accuracy and consistency had to be attained, extensive jigging was used both for the welding and heat-treatment operations.

One blade and head assembly was needed for ground running, another for actual flight and parts of a third for static testing. All these parts, plus others for the airframe, put a heavy load on existing machining capacity despite the purchase of extra equipment; many of the smaller parts were sent out to subcontractors after the machining techniques had been developed by Fairey. Over 500 major components had to be made, some entailing the machining of steel forgings weighing nearly 1700 lb.

Pylon

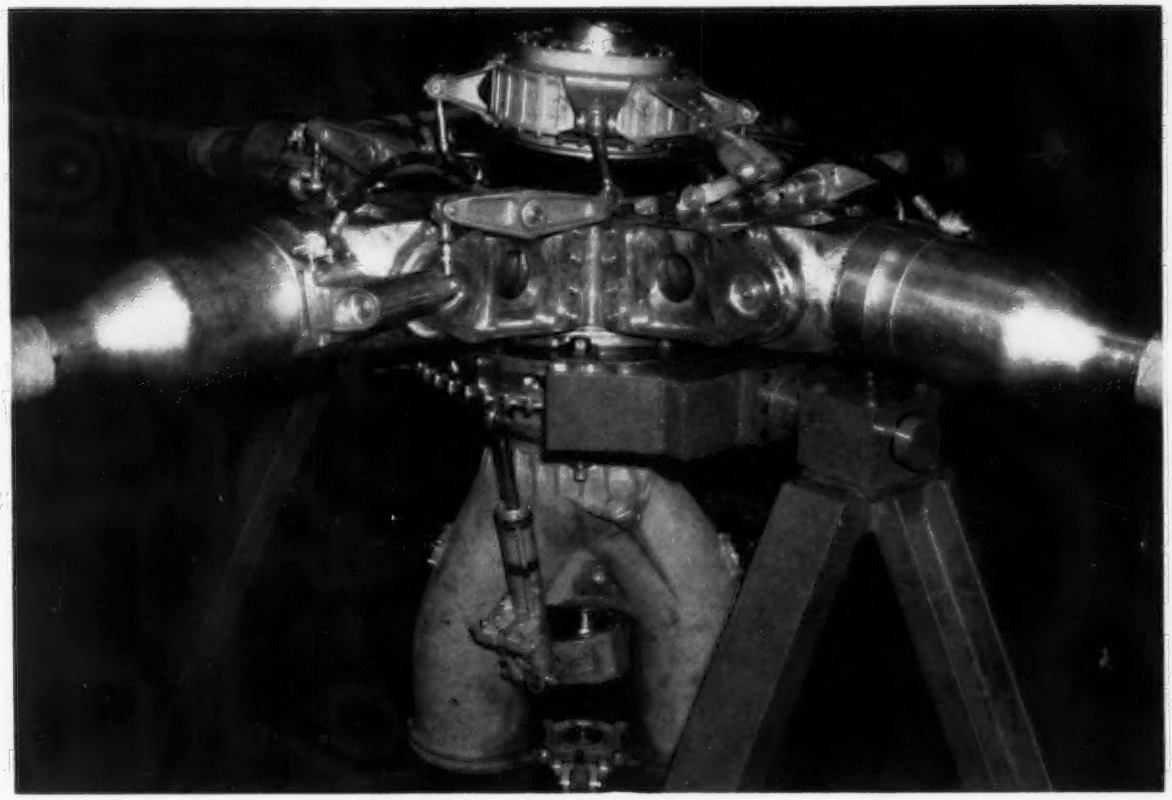
A pin jointed space structure enclosed in a streamline fairing comprises the pylon. Machined end-fittings to tubular members allowed it to be assembled like an "Erector" set. Most of the tubes used were of 17 gage for about five inches at either end with the portion between reduced to 22 gage. Although this amount of stepping is outside the usual manufacturing range, it was accomplished without difficulty. In addition, a surface finish of 32 micro-inches was obtained both inside and out on lengths of eight ft.

One-Piece Wing

With a span of only 46½ ft, the one-piece wing has a parallel chord with slightly rounded tips; gross area is 475 sq ft. It has a relatively simple structure based upon two spars spaced well apart. These are of the usual tension-field type, with "L" section boom. Ribs vary from the shear-web type to pierced thin frames in the region of the fuel bays. Thin internal skins are Redux bonded to the ribs to give the tanks shape.

Two Napier Eland engines of 3500 ehp each at 12,000 rpm are housed in underslung nacelles at mid semi-span. A bifurcated jet pipe issues exhaust either side of the nacelle slightly aft of the main firewall position. An extension shaft runs through the firewall to drive the auxiliary compressor. Each engine drives a 13-ft diam, four-bladed propeller for normal propulsion and directional control at speeds below 90 mi/hr. Providing sufficient yaw control under all conditions of flight has called for much ingenuity. The compressor clutch units, propeller blade angles, as well as rudder control, must be coordinated to give smooth transition from one condition to another. A rather complex mechanism operated by the rudder pedals controls the sequences.

Few details apart from those that can be observed are known about aerodynamic design. Both the wing and tail areas have been kept well within the rotor diameter, in fact there is probably little variation in downwash velocity across the wing. Airfoil section appears to be about 12 per cent thick and set at an appreciable angle of incidence. It is thought that aerodynamic twist is not used. A short moment-arm and generous area characterize the tailplane which carries fins at its tips. That part of the fin appearing above the tailplane is inclined outboard, and is hinged to lie flat when the rotor is running down. No ailerons or elevators are incorporated, although the design can accommodate them if they prove necessary. A trim tab is provided on the left



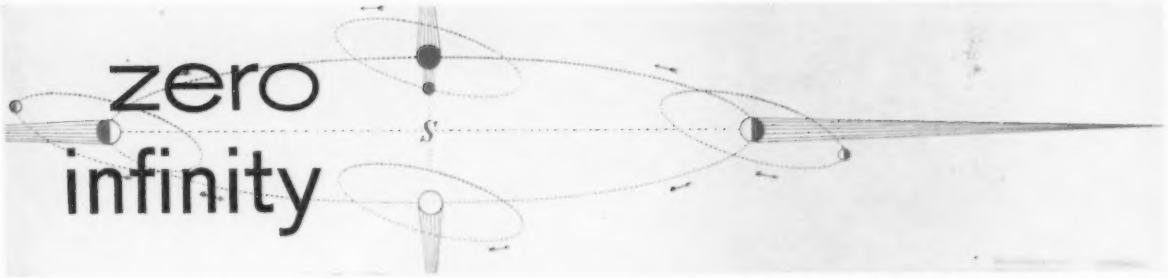
Rotor head assembly shown with underslung air-entry duct. Actuator adjacent to duct is one of two used for cyclic-pitch control.

wing tip and rather large trimming surfaces are fitted to the tailplane.

Fuselage

The short and wide fuselage is designed on the flying packing case principle to allow maximum storage volume. Slab sides and roof have only a slight curvature, while the floor is flat and continuous. Light, closely-spaced frames are joined by intercoastal members with somewhat heavier longerons at the box corners. Similar, but stouter construction, is used for the floor panel which, of course, has an inner and outer skin. Each of the 10 large windows serves a row of seats in the standard 40 seater layout. Considerable simplification is seen when compared with other strutures because pressurization is not employed. Aft of the tailplane two large clamshell doors allow bulky loads to be easily handled. Wheeled vehicles can be driven or rollled straight in. Because of the tricycle landing gear (of the retractable type), the floor is level and has a low threshold. A passenger door in the front fuselage has built in steps and a spring-compensated mechanism for easy operation.

Considerable noise is made by the pressure jets, but their operation is confined to only short periods at the begnining and end of a flight. Vigorous efforts are being made to discover silencing methods, and as a beginning, a relationship between the noise of cold and hot jets has been obtained. With this it is possible to carry out practical work at a faster pace since the test set up can be simpler and more economical. Working on these lines, reductions of 13 decibels have been made, and it is thought that a figure of 20 should be possible shortly.



This department is created to encourage thinking in new dimensions; thinking that is free of the often constraining influence of immediate difficulties. Technological progress is to a great extent based on departures from the conventional or the status quo. That which is considered illogical or impossible to accomplish, has and always will be so only within the limited compass of accumulated knowledge up to a particular date. Speculative thinking is man's most precious asset. It is hoped that this department will provide an outlet for such thinking and will serve to stimulate further ideas. The implications of the symbolism for this department head are that: while the immediate worth of a concept may range from nil to infinity, its true value will only be determined in the ultimate.

hydrogen peroxide

is it a logical source for power, water and oxygen in space flight?

by **Noah S. Davis, Jr.**, special projects branch,
Samuel S. Naistat, manager, inorganic chemicals section,
Food Machinery and Chemical Corp.

Concentrated hydrogen peroxide is not a combustible, yet it possesses certain properties that can be utilized to advantage in space travel. Those applications lie in two areas: enhancing the reliability of the vehicle, and adding to the comfort of the passengers.

The decomposition of hydrogen peroxide can be initiated safely and rapidly with excellent throttle-ability and cut-off. Yet it can be readily stored for lengthy periods without the hazards of toxicity or spontaneous combustion, and without the elaborate storage facilities required for LOX.

Anhydrous hydrogen peroxide (H_2O_2) has become commercially available only in the past two to three years and its potential as a propellant in space vehicles has been presented only vaguely. For propellant use, concentrations above 65 per cent are essential, 90 per cent concentrations have been used almost exclusively for power applications in this country. Lesser concentrations (35 per cent) are used for other commercial applications.

The physical and chemical properties of hydrogen peroxide appear promising for the solution of the following problems associated with space travel:

- Production of heat and power for various uses.
- Maintenance of sealed cabin atmospheres.
- Production of oxygen and potable water.
- Primary propulsion applications.
- Auxiliary power unit applications.
- Guidance applications.
- Ease and safety of handling.

Enhancement of Vehicle Reliability

Already in an advanced stage of development are studies for enhancement of vehicle reliability. Details are proprietary and/or under security restrictions. Nevertheless, sufficient details have been revealed to permit a reasonably adequate discussion.

The logic of attributing high importance to vehicle reliability is understandable. All earth-bound laboratory findings of space medicine will remain academic, as far as humans are concerned, unless the data can be checked on humans in the actual space environment for adequate periods. For example, data on so-called weightlessness over extended periods will necessitate actual orbiting in a satellite. Unless the vehicle is sufficiently reliable, humans would not be permitted to undertake such a journey for obtaining the essential data.

TABLE II

Common Fuel-Oxidant Systems

Oxidizer	Fuel	Combination Temp. (°F)	M	K	Isp (sec.) 500 psia	Av Density (ρ) g (g/cc. 80° F)	Isp. (ρ)
90% H_2O_2	H. C.	4830	21	1.20	248	1.28	317.4
90% H_2O_2	N_2H_4	4690	19	1.22	262	1.24	324.9
HNO_3	H. C.	5150	25	1.23	240	1.30	312.0
HNO_3	N_2H_4	4728	—	—	257	1.25	321.3
HNO_3	NH_3	4220	21	1.24	237	1.12	265.4
LOX	C_2H_5OH	5560	22	1.22	259	0.97	251.2
LOX	H. C.	5770	22	1.24	264	0.955	252.1
LOX	N_2H_4	5370	18	1.25	280	1.065	298.2
LOX	H_2	4500	9.0	1.26	364	0.230	83.7
F	NH_3	7224	19	1.33	306	1.017	311.2
F	N_2H_4	7940	19	1.33	316	1.31	414.0
F	H_2	5100	8.9	1.33	373	0.269	100.3

I_{sp} = specific impulse (lb/lb/sec)
P = average density of mixture (g/cc at 80° F)
M = average mo l.wt. of combustion products
K = average ratio of specific heats
and

$$I_{sp} = \frac{F}{W}$$

where F = thrust (lb) and W = total propellant flow rate (lb/sec)

Hydrogen Peroxide a Safe Power Source

An attribute of concentrated hydrogen peroxide is the ease with which its decomposition can be initiated safely and rapidly with excellent throttleability and cut-off by passage over suitable catalysts. In addition, when handled in accordance with standardized procedures, it can be readily stored for lengthy periods without decomposition or toxicity hazard, spontaneous decomposition amounting to less than 1 per cent per year at ordinary ambient temperatures.

Water provides an immediate and permanent antidote to accidental spillage on the skin or on a catalytic substance, thus preventing or extinguishing any combustion which might be accidentally initiated. From the storage and handling point of view, liquid oxygen (LOX) requires more elaborate storage facilities; in addition, the rapid evaporation rate of the LOX provides a highly oxygenated atmosphere which may support combustion of a fire caused by other means. Nitric acid, another widely used liquid oxidant, although possessing some obvious assets, also is at a disadvantage as far as safety to personnel is concerned. The de Havilland Engine Co. came to the conclusion that the toxicity, and extreme corrosiveness of nitric acid rendered it practically unuseable in manned aircraft; separate British government investigations concurred with this opinion.

To understand why H_2O_2 is so useful a chemical for the generation of steam, oxygen and power, certain of its intrinsic physical and chemical properties must be understood. The decomposition of 1 lb of 90 per cent H_2O_2 (25°C at 1 atmosphere) results in the evolution of 1100 BTU; with 100 per cent H_2O_2, 1240 BTU are evolved from the same amount of fuel. Table I shows the gas volumes and temperatures attained by the complete decomposition of hydrogen peroxide of various concentrations into O_2 and H_2O.

Specific Applications

The mixture of hot steam and oxygen from decomposing concentrated H_2O_2, are employed as the power source for auxiliary power units (APU's) to furnish power for pumps and various other electrical devices in our current crop of ballistic missiles. The chemical energy released drives a turbine to rotate a pump or electric generator.

TABLE 1

Gas Volumes and Adiabatic Decomposition Temperatures from Aqueous Hydrogen Peroxide

Weight, Percent H_2O_2	Gas Volume**	Adiabatic Decomp. Temp.	Percent Vaporization of H_2O
100	6643	1824	100%
90	5233	1364	—
80	3870	908	—
70	2545	452	—
65	1906	228	100
60	1672	212	88.3
50	1287	212	65.5

** Cu. ft. gas per cu ft. of original solution at 20°C. Temperatures and gas volumes at 1.0 atmosphere. Initial conditions—Liquid at 20°C. (68°F.)

A typical gas generator system for a turbopump drive has been used to power the fuel and oxidant pumps of the Viking and Vanguard research rockets, pumping approximately 40 lb of rocket propellant per lb of 90 per cent H_2O_2 used in the 90 to 100 sec of operation. Such hydrogen peroxide gas generators are also employed in the engines of the first stage Redstone and Jupiter C missiles.

Since the stratosphere's reduced density does not provide sufficient bite for the directional

continued on next page

hydrogen peroxide

continued

fins of a rocket when attaining such altitudes, hydrogen peroxide motors are used to keep the main rocket on its desired course. Guidance of the first stage Vanguard rocket will be aided by the high velocity steam-oxygen exhaust of the turbo-pump system, the exhaust gases making their exit through a rotatable jet. The desirability of versatile and reliable power guidance of the type described for space travel application is self-evident.

As a primary propellant, H_2O_2 has been used both as a monopropellant and as a bipropellant. In the Reaction Motors' "Rocket-on-Rotor" application, for helicopters, it has been used as a monopropellant for booster-power application. When passed through small catalyst chambers mounted on the rotor tips of a helicopter, the hydrogen peroxide is decomposed and the exhaust jet is used to provide additional driving power for the rotor. A similar application is to be found in the Rotor-Craft Corporation's "Pinwheel" helicopter, which used H_2O_2 as the sole propellant.

As for applications in manned aircraft of the conventional type, hydrogen peroxide is used as the oxidant in the fully developed de Havilland Super Sprite rocket engine. This engine is being flown on the Vickers Valiant and Saunders-Roe (SR53). These applications are cited to indicate the state of reliability which British engineers have attained with systems using hydrogen peroxide as an oxidant for the propulsion of manned aircraft.

Performance

Table II indicates that the LOX-JP system has a somewhat higher Isp than the 90 per cent H202-JP system. However, when the densities of the oxidants are included (as in the last column), the values for H_2O_2 systems are higher. In practice, this means that a given tankage can carry more H_2O_2 than LOX. Omitting detailed missile trajectory equations and computations, if the range of a single stage LOX-gasoline system is taken as 1.00, the following values are obtained for the various systems:

Comparative Ranges of Single-Stage Rockets
(LOX-Gasoline = 1.00)

System	Performance
90% H_2O_2 – NH_2NH_2	0.96
100% H_2O_2 – NH_2NH_2	1.22
LOX – NH_2NH_2	1.22

Passenger Comfort—Speculation Uses

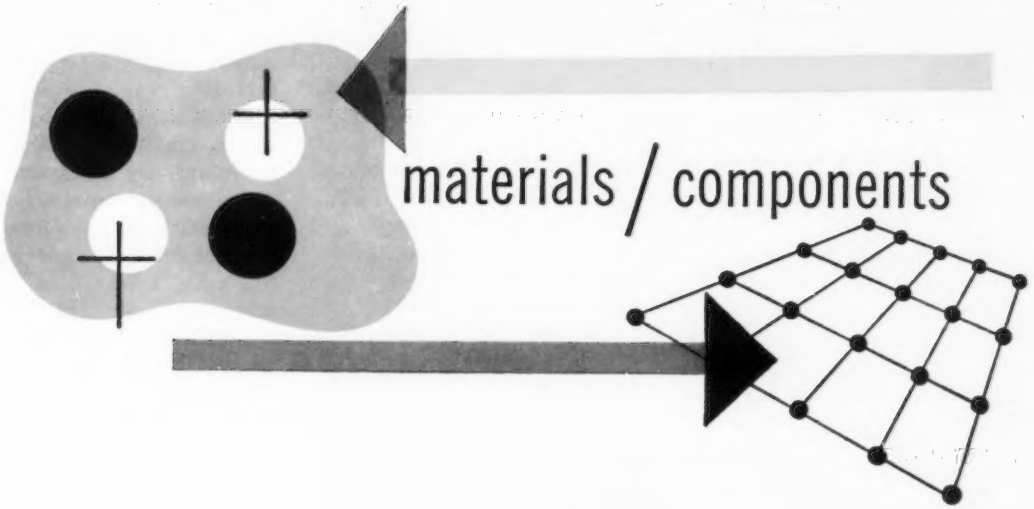
For efficiency of function over extended periods, the crews of manned satellite vehicles should be kept artificially under climatic conditions approaching those at sea level. Above 16 miles, conventional pressurization with outside air is not feasible.

Within a sealed cabin an adequate air supply system and livable temperatures and humidity must be established and maintained. For flights of brief duration LOX may be used as the breathing oxygen source, without excessive container dead weight. However, if the flight is of any extended duration, the dead weight and volume of the LOX storage tanks will be excessive.

A five man crew would use approximately 10 lb of oxygen per day. If this quantity of oxygen were to be obtained from 90 per cent H_2O_2, 136 lb of water would be a by-product, part of it would automatically humidify the oxygen, the remainder would be condensible for obvious additional uses. The container for storing the above 100 lb oxygen as H_2O_2, would be less than 40 lb, and would also serve as the storage container for the water. For a quantity of LOX of the type mentioned, the storage container would be bulkier, of double wall insulated construction, and thus approach the weight of the stored LOX. In addition, a separate supply of water would have to be carried to humidify the LOX to render it suitable for breathing.

A method of controlling temperatures within moderate ranges inside the sealed cabin would be to decompose the H_2O_2 as needed for breathing.

The hydrogen peroxide would flow at a controlled rate through a catalyst chamber of the type used for the helicopter design work; part of the decomposing gases being used to pressurize the tanks. Such an apparatus could be used to run small pumps or fans for maintaining circulation of the atmosphere within the cabin. Condensation of the steam could be carried out on the cooled cabin chamber wall turned away from the sun. The water would then run back into one of the storage drums for subsequent use. The oxygen released would be passed through a suitable purification train prior to being charged to the cabin atmosphere for breathing. The valving of the apparatus would be adjusted to balance heating needs with oxygen evolution. Since the necessary physical constants are all readily available, the preliminary design of a self-contained space cabin using H_2O_2 as the source of breathing oxygen, water, heat and power for blowers should not be an impossibility.



Integral Valve and Shaft In Power Boost Cylinder

Integral valve and shaft design in a line of power boost cylinders provides an econom-

ical over-ride for emergency power-off operation and a compact package for ease of installation and maintenance.

This basic design is being used by the helicopter industry for main rotor pitch control, tail rotor pitch control, and throttle control.

Choice of valve gain curve, low valve force, stroke, porting, and mounting to customer specification are additional features which lend the design to wide aircraft and industrial application.

Conair, Inc.

Circle 101 on postcard for more data

Liquid Cooled Brake Developed for Aircraft

A liquid-cooled brake system for aircraft prevents temperature build-up on braking surfaces by as much as 1500°F.

The disc-type brake, developed and engineered specifically for aircraft removes heat from the critical wheel and brake area and carries it to an exchanger where it is dissipated.

Tests conducted by ARDC's Wright Air Development Center showed that the brake performed consistently without fade in consecutive stops, operating at maximum temperatures below 500°F.

Weight of the liquid-cooled brake system is about the same as for standard brakes now in use.

B. F. Goodrich Aviation Products

Circle 102 on postcard for more data

Glass-Epoxy Laminate for Copper-Clad Laminates

A glass-epoxy plastic laminate has been developed especially for use in making copper clad laminates for printed circuits.

Designated grade GEC-500, the glass base, epoxy resin laminate is furnished either plain or with the copper cladding on one or both sides.

The copper-clad grade can be supplied with the copper bonded to the base laminate with adhesive (Grade GEC-500 Cu Clad A) or without adhesive (Grade GEC-500 Cu Clad NA).

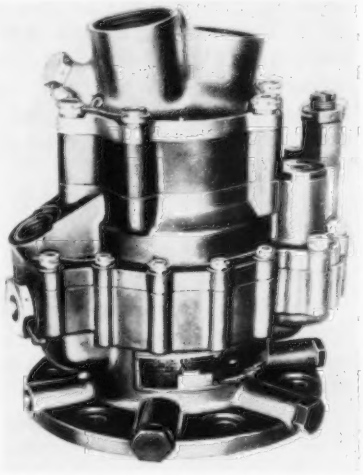
The base laminate meets the requirements of MIL-P-18177A.

Taylor Fibre Co.

Circle 103 on postcard for more data

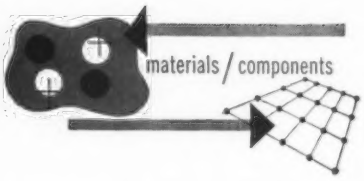
3,000 psi Hydraulic Pumps Can Supply Rated Delivery Demand in Milliseconds

AP6V series hydraulic pumps can produce hydraulic pressures of 3000 psi, at a flow



rate of 16 gpm. They require about 30 hp at normal rated speeds.

The pumps can shift from zero delivery to supply any demand up to maximum volume in



approximately 20 to 30 milliseconds.

The Denison design of a two-stage pump enables operation at lower inlet pressure than other units.

American Brake Shoe Co.

Circle 104 on postcard for more data

Solenoid Can Be Used As Pilot for Large Valves Or as Independent Unit

A high pressure, low capacity, direct acting solenoid

valve designed for pilot operation of larger valves can also be used as a direct acting on-off valve in small hydraulic systems, and high pressure lubricating systems. When two or more are mounted on a sub-plate, they can be used as a three or four-way valve.

The unit is designed for 3,000 psi, and delivers 17 cu. in./min at 100 psi pressure drop, weight is 4.5 oz.

The valve handles hydraulic oils, kerosene or lubricating oils. It is available in 6 to 48 dc and 110 ac.

Sarasota Precision Products, Inc.

Circle 105 on postcard for more data

Brazing Stop-Off Material Acts As Parting Compound

A new Nicrobraz stop-off material acts as a parting compound to prevent the brazing of not-to-be-brazed mating surfaces during furnace brazing operations.

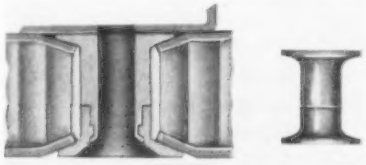
Named White Stop-Off, the new parting material is supplied in powder form. In use, it is mixed with a volatile plastic, called Nicrobraz cement, to facilitate application.

Wall Colmonoy Corp.

Circle 106 on postcard for more data

Honeycomb Spacer Fits Variety of Parts

A low-cost, two-piece honeycomb spacer that does not depend on the selective fit of



parts for assembly is safe and easy to install.

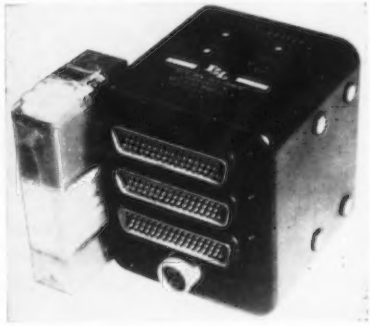
Ordinary drill sizes are used for the installation hole in the sandwich structure. The spacer is placed in the hole and a grommet visually aligned over the spacer. The mating parts are quickly set by a simple inexpensive setting tool. When installed, a grommet is locked positively in place by the flaring over of the lip at the top of the spacer into the locking groove of the grommet. The fastener may be quickly removed by drilling out this swaged over flange.

Shur-Lok Corp.

Circle 107 on postcard for more data

Commutator Houses Motor In New Design Concept

A subminiature high speed sampling switch based on a new



design concept results in a 50 per cent reduction in overall volume for a given number of circuits.

In this unit, the 400 cycle, 115 v, single-phase drive motor is completely contained inside the commutating rings. An integral gear box drives 3 poles with 45BBM contacts at 20 rps. This 3¼ x 3¼ x 3-1/16 in. hermetically sealed switch weighs approximately 3 lb and provides both high and low level bounce-free contact operation.

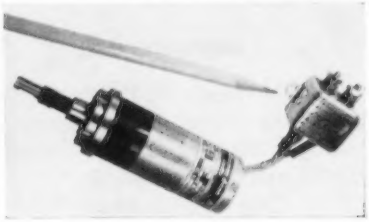
Instrument Development Laboratories

Circle 108 on postcard for more data

DC Gearmotor Incorporates Thermal Protection

A miniaturized 27 v dc permanent magnet gearmotor with thermal protection and radio frequency filter also has an extended shaft with special bearings to compensate for an overhung load.

Identified as Model P7P6TFRP80, it develops 180



in. oz maximum stall torque and 16 in. oz running torque.

The gear reduction provides an output speed of 1000 rpm at full load and 1400 rpm at zero load.

Western Gear Corp.

Circle 109 on postcard for more data

Teflon 100-X Available on High Temperature Wire

High temperature wires using Teflon 100-X as both primary insulation and jacketing material are now available.

Wires insulated with Teflon 100-X exhibit most physical electrical and chemical characteristics of conventionally extruded Teflon-6 wires, but unlike

the latter they are available in long, continuous lengths.

Where Teflon 100-X is used as primary insulation the wires meet all the requirements of MIL-W-16878, Type E.

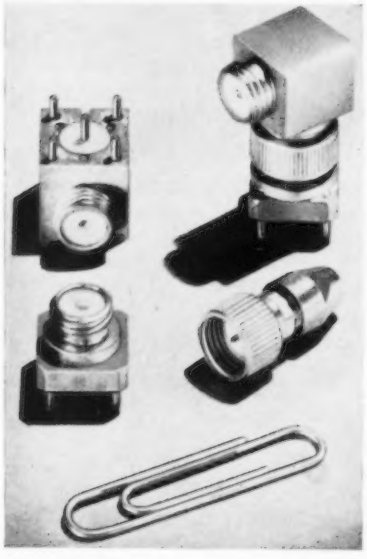
William Brand and Co.

Circle 110 on postcard for more data

Coaxial Connectors Available in Miniature Sizes

A series of miniature coaxial connectors designed for use with coaxial cable and for mounting on printed circuit boards is available in a 50 ohm constant impedance group, 50 ohm nonconstant impedance group, and 93 ohm nonconstant impedance group.

Connector bodies are brass with albaloy plating, insulation is machined Teflon.



Rated voltage for the series is 500 dc. Mounting pins are for standard 5/32 in. line spacing.

H. H. Buggie, Inc.

Circle 111 on postcard for more data

Acrylic Laminating Resin Is Free of Aromatics

Lucite sirup, an all acrylic laminating resin, is tailored especially for the impregnation of fibrous reinforcement and can be handled in much the same manner as conventional laminating compositions. The

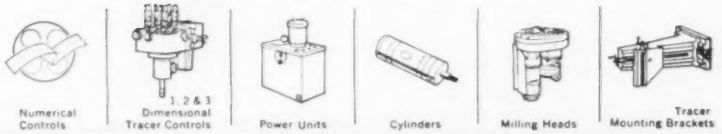
Helping Leading Manufacturers Give You Better Machine Tools!

We at True-Trace are proud to be a part of and contribute to the above manufacturers' reputation in producing accurate, dependable tracer and numerically controlled machines–equipment that can be counted upon to produce the precision, complex parts so vital in today's metalworking industry. These leaders know they can depend upon True-Trace machine tool controls to do the best job. After complete investigation of various control systems available, they, with others, have selected True-Trace as original equipment.

When you think of new machinery for your plant expansion or modernization... look to these leaders for quality equipment you can count on. Or–if you're considering the conversion of existing manual machines to tracer or numerical control... do as the leading machine tool builders have done–specify True-Trace!

"More True-Trace Machine Tool controls are used as original equipment by more machine tool builders than all other control systems combined."

"Sponsor of the Contour Machining Conferences"



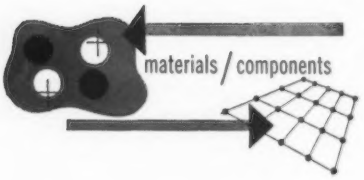
TRUE-TRACE SALES CORPORATION

9830 E. Rush St., El Monte 35, California

Branch Plants: 35 Urban Ave., Westbury, Long Island, New York

2401 Eaton Lane, Racine, Wisconsin

Dealers in Principal Cities



good properties of laminates made with acrylic sirup result largely from the absence of aromatic components normally present in other compositions.

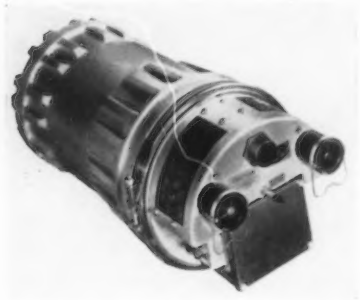
The resin is a clear, colorless liquid and can be processed by methods now used in the reinforced plastics industry, including contact pressure, press lamination, and premix.

Du Pont

Circle 112 on postcard for more data

Airborne Inverter Weighs 68 Pounds

An airborne inverter power supply has been designed to invert 27.5 dc to a regulated source of 115/200 v, 400 cps ac



at 3500 v-amp load, for various components within an airframe.

Weighing 68 lb and measuring less than 19-in. length by 11-in. diam, the Model 433 inverter may be modified at the factory to provide volt-amperes ranging from 1500 to 3500 depending upon application requirements.

The inverter is available with air or liquid cooling.

Western Design & Mfg. Corp.

Circle 113 on postcard for more data

Elastic Hanger Cord Needs No Shock Absorbing Rig

Designed to support self-sealing fuel cells within a wing structure, this elastic hanger cord has been found useful in a variety of other applications where wires or cables must be suspended. The elastic portion of the cord is extruded from chloroprene synthetic rubber

with a 7/32 in. diam. The ends of the cord have brass hooks that may be closed or open.

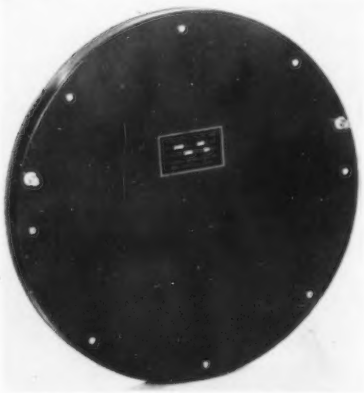
The synthetic rubber resists attack from aromatic fuel, oil, and ozone. Recovery from stretching is slower than that of natural rubber which precludes any requirement for shock-absorbing arrangement.

William H. Snow Co.

Circle 114 on postcard for more data

Ultrasonic Delay Lines Are Smaller and Lighter

A series of solid, ultrasonic delay lines are smaller and lighter than previous units, and especially designed for radar and computer applications for



which a nominal repetition frequency of 360cps is required.

A delay line for 20 megacycles operation, having a delay of 2778 microseconds, has a case diam of 13 in. and 1¼ in. thick.

The spurious signals are 45 db below the delayed output, and the attentuation is 50 db into 270 ohm tuned load.

Anderson Laboratories

Circle 115 on postcard for more data

Silver-Cadmium Oxide Clad Electrical Contact Tapes Offer Cost Savings

Silver-cadmium oxide (Ag-CdO) clad electrical contact material is now available as a continuous coil of tape. The advantage of tape in making Ag-CdO faced electrical contact assemblies is one of cost.

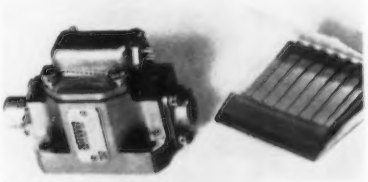
Tape contact materials are pre-formed to finished cross-sectional shapes. Rolling to finished form also produces a hardness considerably above that of brazed contacts of Ag-CdO. To facilitate welding, contact tapes are supplied with various types of projections, the most common being a knurled type.

Metals & Controls Corp.

Circle 116 on postcard for more data

Electro-Hydraulic Servo Valve Has Dry Coil

A dry coil, two-stage electro-hydraulic servo valve 20 per



cent lighter than other servo valves of similar capacity has been designed primarily for aircraft and missile applications requiring hydraulic flow proportional to small electrical input signals.

The torque motor is a polarized relay type with rated differential current of 8 ma. Valve models with rated load flow of 2.5 or 5 gpm are available. Both models measure 3.08 x 1.75 x 1.83 in. Total weight is only 9.3 oz.

Vickers, Inc.

Circle 117 on postcard for more data

DESIGN

There's a Place for High-Pressure Pneumatics as well as Hydraulics.

H. E. WRIGHT. *SAE Journal*, (March 1958), 5 pp.

A comparison of these two systems is made by considering separately performance criteria of actuating cylinders, transmission lines, and energy sources.

Post-Formed Phenolic Laminates.

Prod. Eng., (February 17, 1958), 3 pp.

Design data given for shaping of parts from pre-laminated sheet stock, considered economical for certain applications.

Sandwich Manifolding.

A. A. DICKE. *Prod. Eng.*, (February 17, 1958), 2 pp.

Advantageous applications of integrated hydraulic passageways are discussed.

Chart Eases Moment-of-Inertia Calculations.

W. G. FLANNELLY. *Prod. Eng.*, (February 17, 1958), 2 pp.

Graphic method of calculation presented to avoid the conventional method of splitting involved shapes into many small rectangles for this purpose.

Bearing Rotation and Reversal Averages Spurious Torques.

Design News, (March 3, 1958), 2 pp.

New directional Sperry gyro significantly reduces its random drift rate by averaging out the error-producing torques induced by sensitive-axis ball bearings.

Explorer I.

Jet Propulsion Laboratory. *Astro.*, (April 1958), 4 pp.

Details given on Explorer launching vehicle and instrumentation, also on flight mechanics used to orbit satellite.

Cooling the Lockheed Electra.

B. L. MESSINGER. *SAE Journal*, (February 1958), 3 pp.

Electrically-powered, 10-ton capacity system is described, incorporating air and vapor cycle refrigeration for both ground and air operation.

Rotating-Thrust VTOL Proves Feasible.

J. A. O'MALLEY, JR. SAE *Journal*, (March 1958), 6 pp.

Basic theory and some current trends are discussed.

MATERIALS and PROCESSES

Are Tool Steels the Answer to High-Speed Flight?

J. H. MAINHARDT and J. P. WRIGHT. *Amer. Mach.*, (March 10, 1958), 5 pp.

Discussion on formability, machinability, decarburization control, and heat treatment of hot-work tool steel in both sheet and bar form.

Application of Dry-Film Lubricants in Plain Bearings.

M. H. WEISMAN. Mach. Des., (February 6, 1958), 4 pp.

Types, applications, characteristics and specifications are discussed.

High-Integrity Aluminum Castings.

A. R. MEAD. *Prod. Eng.*, (February 17, 1958), 3 pp.

Method used at Grumman Aircraft outlined, to promote reliability in aluminum-alloy castings.

Continued on next page

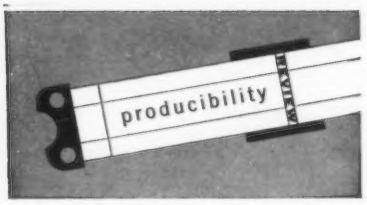
REVIEWED IN THIS ISSUE

Periodicals and Papers

Air Force Air Force Association
Amer. Mach. American Machinist
Astro. Astronautics
Design News Design News
Flight Flight (British)
Mach. Des. Machine Design
Mach. Machinery
Prod. Eng. Product Engineering
SAE Journal Society of Automotive Engineers Journal

Books Received

Materials Handling Equipment • Chilton
Engineering Data on Thread and Form Rolling • Reed Rolled Thread Die Co.



Adhesive-Bond Future Challenged by 1000°F Uses.

K. BUCHELE. SAE Journal, (March 1958), 2 pp.

An overall glance at current applications and methods, drawn from SAE Production Forum discussions.

Asbestos Reinforced Plastics for Rockets and Missiles.

D. V. ROSATO. *AMM*, (January 1958), 6 pp. The physical properties and potential applications of the latest asbestos reinforced plastics are given in detail.

PRODUCTION

Making the P.1 Wing.

Flight, (January 10, 1958), 5 pp.

Details of the structural design and production problems related to English Electric P.1 supersonic fighter are presented.

Where Stainless Is Lighter than Aluminum.

J. B. TEETER and R. ROHRBERG. *Amer. Mach.*, (March 10, 1958), 2 pp.

Manufacturing process for "Anti-ice" nozzles used in F-100 fighters is described.

New Extrusion-Fabrication Process Reduces Jet Engine Parts' Costs.

N. J. FEOLA. *SAE Journal*, (February 1958), 5 pp.

In process developed by Curtiss-Wright ring-shaped titanium jet-engine parts are made by extruding a suitable cross-section in strip form, cutting the strip, bending into a circle, and welding together the ends.

Now We Buy Tapped Holes . . . Not Taps.

C. MATHEWSON and E. STUTZ. *Amer. Mach.*, (March 10, 1958), 2 pp.

Discussion of gains realized by specifying the taps to be purchased in terms of the requirements of the holes they were to tap. Tap-procurement form included.

Spotwelding Titanium Is Practical.

W. R. GAIN and D. E. WAITE. *Amer. Mach.*, (March 10, 1958), 3 pp.

Various applications for sandwich assembly are presented.

The Growing Versatility of Ultrasonic Machining.

J. WELCH. *Mach.*, (February 1958), 5 pp.

Certain current trends in equipment, materials, and applications are presented.

Alignment of Telescope Barrels Require Precision Machining.

A. BLANKEN. *Mach.*, (February 1958), 4 pp.

Method of fabrication for these optical tooling components is given.

Realizing the "Impossible" in Precision Bending.

F. J. FUCHS. *Mach.*, (February 1958), 13 pp.

Detailed description of method utilized in manufacture of waveguides with internal tolerances of ± 0.003 in.

Chemical Milling Provides Many Advantages.

DR. D. G. MITTON. *SAE Journal*, (March 1958), 2 pp.

Design applications, advantages, and present limitations of the process are reviewed.

General Interest

Who's Who in Missile Contracting.

Astro., (April 1958), 4 pp.

A listing of missiles, components, prime contractors, and principal subcontractors.

A Ballistic Missile Directory.

Air Force, (March 1958), 12 pp.

Directory of prime contractors and major subcontractors in the nation's ballistic missile program.

A Military Astronautics Glossary.

Air Force, (March 1958), 5 + pp.

A brief presentation of basic terms and definitions encountered in this growing field.

Books Received

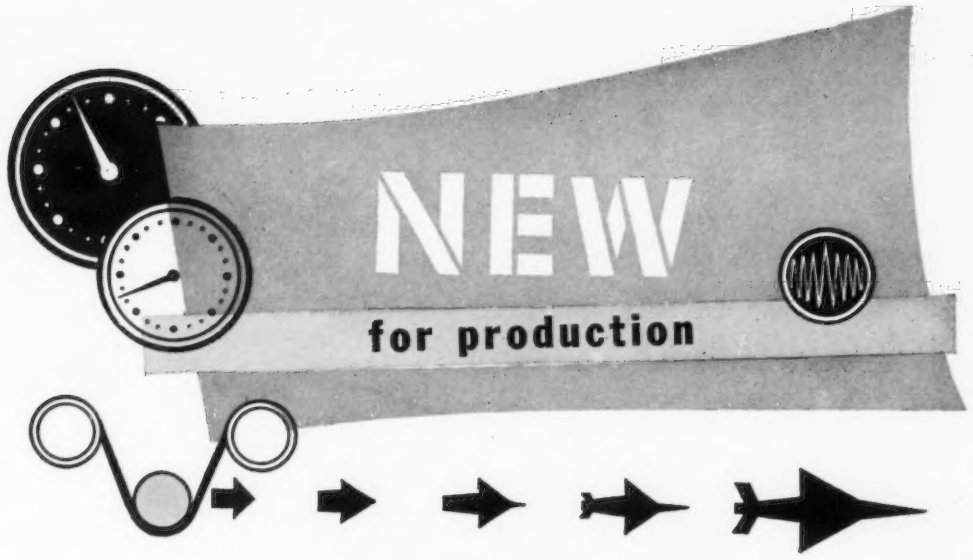
Materials Handling Equipment. D. O. HAYNES. Chilton, 1957. 636 pp. $17.50.

Comprehensive coverage of equipment and systems, including also descriptions of basic mechanical principles of operation related to each system. This book is divided into seven major sections as follows: Transporting Equipment, Elevating Equipment, Conveying Equipment, Transferring Equipment, Self-Loading Equipment, Bulk-Handling Equipment, Accessory Equipment. Chapters are also devoted to storage batteries, their selection and care, electric motors, etc.

Engineering Data on Thread and Form Rolling.

Reed Rolled Thread Die Co., 1957. 87 pp. $1.50.

This pamphlet has been compiled to provide comprehensive data on thread and form rolling for product design engineers, tool and method engineers, and manufacturing and inspection departments. Included also are types of equipment and tools used for various rolling operations.



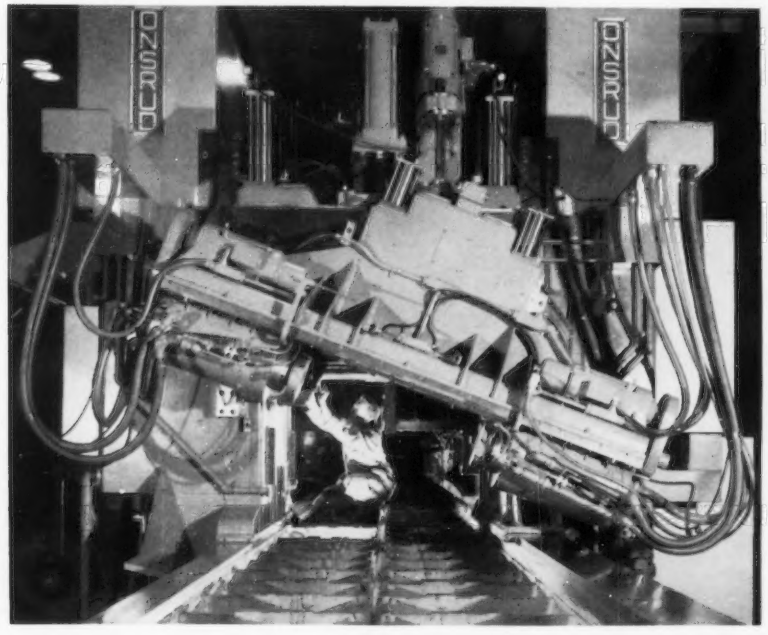
CONTOUR MILLER BOOSTS SPEED AND ACCURACY

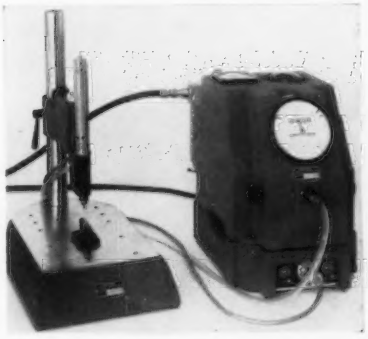
The A90-36A automatic contour milling machine provides electro-hydraulic drive for the critical feed components of multiple feed milling heads so that production speed and accuracy can be maintained throughout a milling operation. The result is an overall increase in speed or accuracy of more than 100 per cent.

A resolution accuracy to a tolerance of 0.0005 in. and a part-to-part reproducible accuracy to a tolerance of 0.0015 in. This latter tolerance is held at a feed of 60 in./min on a radius of ½ in. As radii increase, precision increases. The machine is equipped with six milling heads and has a work area 3 ft wide and 60 ft long.

Onsrud Machine Works, Inc.

Circle 164 on postcard for more data





MEASURING GAGE EXERTS ONLY SLIGHT PRESSURE

Extremely delicate parts such as light springs, bellows, diaphragms, and vacuum tube grids can be measured without fear of distorting them, by means of a "pressureless" comparator.

This Air-Electronic gage is called pressureless because the sensitive gaging contact exerts practically no pressure on the workpiece. In fact, actual testing shows that it amounts to only 0.005 gm or approximately 1/10,000 oz. The extremely low gaging pressure is obtained through an ingenious arrangement in which the sensitive gaging contact is raised and lowered by a special type of wire. The wire has rapid response to heat

and is made to fluctuate in length by being alternately heated and cooled.

Federal Products Corp.

Circle 165 on postcard for more data

BUCKLE FOR TIE-DOWN USES RATCHET TAKE-UP

Designed to withstand a 5,000-lb. load, a buckle features a ratchet type take-up mechanism for tensioning heavy web belting, used in cargo tie-down, for any desired load less than capacity. The unique device has a quick release feature. The buckle was developed to solve

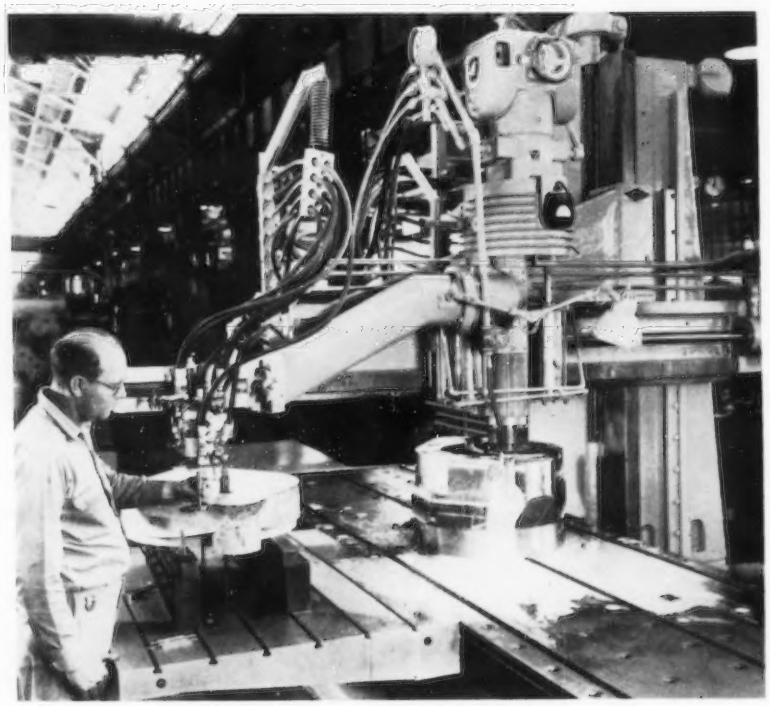
military cargo handling problems. Missile manufacturers are already using it.

The buckle may be utilized with a short length or strap on a cargo net; or, with longer lengths, used between anchor joints in trucks, cargo aircraft, industrial materials handling equipment, and in ship cargo holds.

Any webbing, up to a max width of 1-23/32 in. and max thickness of 5/32 in., may be used.

Aeroquip Corp.

Circle 166 on postcard for more data



HARD WORKING TOOL MADE FROM OUTMODED PLANER

A "new" three-dimensional tracer-controlled milling machine pinpoints the practicality of converting outmoded machinery into hard working production tools. Underneath the versatile and modern-looking miller is an old open-side (48 x 48 in. x 16 ft) planer.

First step was to modify the planer so that all machine movements were hydraulically operated. A tee-slotted plate was then made to serve as a template or master-form mounting base. This was attached to the outboard side of the table and may be positioned at any point along its 16-ft length.

In this conversion a 25-hp variable-speed spindle was used to replace the tool mount. Using two geared speed ranges, the spindle provides constant horsepower at speeds from 60 to 3000 rpm. Two small hydraulic cylinders, mounted on opposite sides of the spindle housing, control the 8-in. vertical travel of the milling head. For certain applications, the milling head is easily swiveled 45 deg each side of vertical. Feed rates for all movements range from 0 to 25 in./min.

Romulus Tool & Engineering Co.

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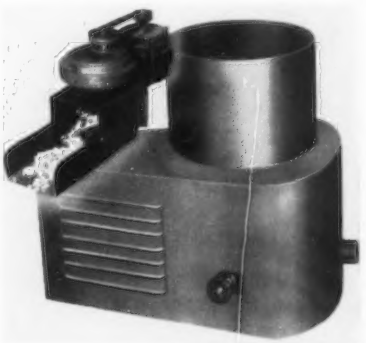
WASTE CONVERTED TO PULP; PIPED TO EXTRUDER

Mechanized handling of waste by the Conservomatic System provides for conversion of paper, books, cardboard, cellophane, pliofilm, glass, and other waste into a greatly reduced odorless pulp that is semi-dry and easily handled. This



system eliminates any possibility of secret information be-

Continued on page 69

for full facts on

new materials and components
new production equipment
advertiser's products and services
copies of technical literature

To keep well informed on new products and production equipment, use AIRCRAFT and MISSILES MANUFACTURING'S free reader inquiry service. The new materials, components, technical literature, and production equipment advertised and described editorially in this issue are numbered consecutively and keyed to the post cards below. When information is wanted, circle the corresponding key number on the post card. Extra cards are included for your associates with whom you share your copies of AIRCRAFT and MISSILES MANUFACTURING.

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4 **Acme Tank & Welding Co.**
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23 **American Pullmax Co.**
Machine, sheet metal
9 **American Welding & Mfg. Co.**
Rings, bands & assemblies, welded
3 **Burgmaster Corp.**
Drill, bench model turret
5 **Cincinnati Milling Machine Co.**
Machine, hydrospin
13 **Colonial Romulus Div.**
(to come) ....
11 **Electric Steel Foundry**
Fittings, special
10 **Elox Corp. of Michigan**
Wheel, turbine rotor
8 **Federal Products Corp.**
Gages, precision
7 **Gear Grinding Machine Co.**
Grinders, precision
24 **Grieve-Hendry Co., Inc.**
Ovens, recirculating
1 **Heald Machine Co.**
Analysis, replacement
18 **Hunter Mfg. Co.**
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12 **Hydroforming Co. of America**
Parts, hydroforming
17 **Kaman Aircraft Corp.**
Housings & chassis for airborne electronics
14 **Magnaflux Corp.**
Systems, test
26 **Mechanical Mfg. Co.**
Parts: hydraulic control, jet engine, and missiles
20 **Power Sources, Inc.**
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19 **Sealol Corp.**
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Lubricants, ultra-high temperature
22 **Stewart Corp., F. W.**
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27 **Synchro Start Products**
Switches, speed sensitive
25 **Titan Tool Co.**
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16 **Trutrace**
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108 **Commutator, motor-housing**
Instrument Development Laboratories
111 **Connectors, coaxial**
H. H. Buggie, Inc.
101 **Cylinder, power boost**
Conair, Inc.
115 **Delay lines, ultrasonic**
Anderson Laboratories
109 **Gearmotor, miniaturized**
Western Gear Corp.
113 **Inverter, airborne**
Western Design & Mfg. Corp.
103 **Laminate, glass-epoxy**
Taylor Fibre Co.
106 **Parting agent, brazing**
Wall Colmonoy Corp.
104 **Pump, hydraulic**
American Brake Shoe Co.
112 **Resin, acrylic, laminating**
Du Pont
117 **Servo, electro-hydraulic**
Vickers, Inc.
105 **Solenoid valve, pilot**
Sarasota Precision Products, Inc.
107 **Spacer, honeycomb**
Shur-Lok Corp.
114 **Suspension cord, elastic**
William H. Snow Co.
116 **Tape, electrical contact**
Metals & Controls Corp.
110 **Wire, coated, high-temperature**
William Brand & Co.

Alphabetical List of Companies

104 **American Brake Shoe Co.**
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239
Circuit tester, synchro
Associated Missile Products Co.

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107 **Shur-Lok Corp.**
Spacer, honeycomb
114 **William H. Snow Co.**
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103 **Taylor Fibre Co.**
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117 **Vickers, Inc.**
Servo, electro-hydraulic
106 **Wall Colmonoy Corp.**
Parting agent, brazing
113 **Western Design & Mfg. Corp.**
Inverter, airborne
109 **Western Gear Corp.**
Gearmotor, miniaturized

NEW FOR PRODUCTION

Alphabetical List of Products

174 **Boring tools**
Giddings & Lewis Machine Tool Co.
170 **Boring machine, vertical**
Snyder Tool & Engineering Co.
166 **Buckle, cargo tie-down**
Aeroquip Corp.
165 **Gage, measuring**
Federal Products Corp.
175 **Gaging machine, hole locator**
The Sheffield Corp.
173 **Grinding attachment**
Gebhart Machine Tools, Ltd.
172 **Jig borer**
Pratt & Whitney Co., Inc.
164 **Milling machine, contour**
Onsrud Machine Works, Inc.
167 **Milling machine, tracer-controlled**
Romulus Tool and Engineering Co.
171 **Stud driver**
Titan Tool Co.
168 **Waste disposal system**
Conservomatic Corp.
169 **Welding outfit**
The K-G Equipment Company, Inc.

Alphabetical List of Companies

166 **Aeroquip Corp.**
Buckle, cargo tie-down
168 **Conservomatic Corp**
Waste disposal system
165 **Federal Products Corp.**
Gage, measuring
173 **Gebhart Machine Tools, Ltd.**
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174 **Giddings & Lewis Machine Tool Co.**
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Alphabetical List of Items

227
Armature winder
Geo. Stevens Mfg. Co., Inc.

241
Castings
Castings Engineers, Inc.

239
Circuit tester, synchro
Associated Missile Products Co.

238
Deburring machines, automated
Acme Manufacturing Co.

235
Drilling control, automatic
Stromberg-Carlson Co.

226
Force gages, mechanical
W. C. Dillon & Co., Inc.

230
Generator, air turbine
General Electric Co.

234
Infrared application
Servo Corp. of America

237
Lockers, storage, steel
Penco Metal Products

229
Magnetic shields
Perfection Mica Co.

244
Manometers
Exactel Instrument Co

232
Mechanical equipment manufacturing
Tri-Kris Co., Inc.

228
Production facilities, rocket
The M. W. Kellogg Co.

240
Relays, miniature
Iron Fireman Manufacturing Co.

243
TV system, closed-circuit
Insul-8-Corp

242
Temperature controls
Fenwal, Inc.

231
Tracer control system
The Monarch Machine Tool Co.

236
Welding, electric
Linde Co.

233
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Continued from page 64

ing resurrected from partially burned or incompletely destroyed documents.

Basically, the system (see illustration) consists of a pulper, a pump, and an extruder (inset). Operation is completely automatic. Refuse is dumped into a tank, and small amount of water is added to change the waste to a liquid pulp. The liquid pulp is discharged into a 2-in. pipe that is connected to the extruder (inset). The extruder removes water and pushes the pulp into a container.

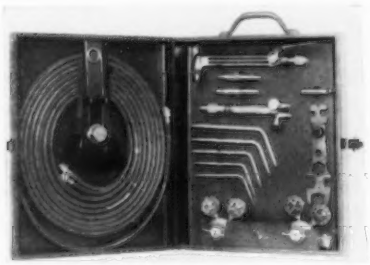
Disposal rate is 800 lb of paper per hour. A larger unit disposes of a ton per hour. Waste is reduced up to 80 per cent by volume and the odorless pulp can be disposed of by a normal composting process.

Conservomatic Corp.

Circle 168 on postcard for more data

PORTABLE UNIT SOLDERS, BRAZES, CUTS, AND WELDS

Weighing only 12 lb, a packaged welding outfit, called the Redi-Set, includes all the

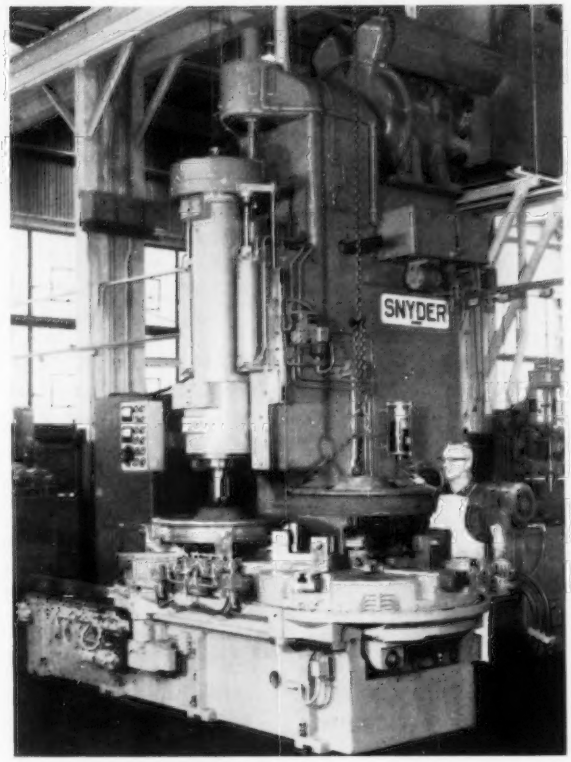


necessary equipment for brazing, cutting, welding, soldering and heating. It brazes small tubing, cuts up to 4-in. armor plate, and welds ½-in. thickness.

The K-G Equipment Co., Inc.

Circle 169 on postcard for more data

VERTICAL BORING MACHINE USES AUTOMATION TECHNIQUES



Low-production automation techiniques are used by a vertical boring machine to speed the production of parts weighing up to 700 lb. Piece is loaded into a two-position, line-index type fixture, while another is being bored.

The spindle of the machine is powered by a motor provided with a variable speed drive to accommodate a variety of bore sizes. Hydraulically-operated five-jaw chucks permit the holding of parts of different diameters. A separate hydraulic power pack supplies power for operating the chuck, table, and spindle feed cylinders. A 7-ft long spindle, supported by two tapered roller bearings at the top, and one at the bottom, permits the machine to produce heavy parts having long, large-diameter bores while holding stringent hole straightness and size tolerances.

Snyder Tool & Engineering Co.

Circle 170 on postcard for more data

NO TOOLS NEEDED TO ADJUST STUD DRIVER

The Mustang is designed to drive studs where limited space demands a driver of small diameter. Two models are available. Max capacity on one is ⅜ in.; and the other, 9/16 in.

In addition to having a small diameter, this driver can be adjusted for various lengths of grip on the stud. The method of adjusting is positive; it cannot slip or become loose. No

wrenches or tools of any kind are needed to loosen or tighten the adjustment.

Titan Tool Co.

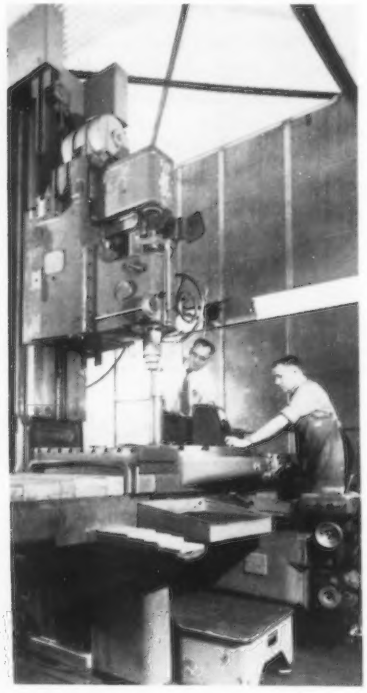
Circle 171 on postcard for more data

JIG BORER IS 26 TON GIANT

"The largest and most accurate jig borer in the world," a 26-ton giant machine, can accommodate workpieces as high as 70 in. and can bore to the center of a workpiece 80 in. diam. They come equipped with a combination built-in 48-in. rotary table and 36 x 78 in. rectangular table.

All models incorporate Electrolimit system of measurement.

Once set in motion, they perform their work with the



highest degree of accuracy and without human intervention. Automated machines with this system of "Numerical Control" increase production rates, reduce cost of manufacture and eliminate the factor of human error in highly precise machining operations where great accuracy must be achieved.

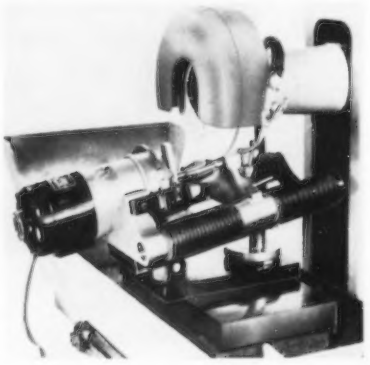
Known as the 4EA Electrolimit Jig Borer, the new machine towers approximately 16 ft above floor level.

Pratt & Whitney Co., Inc.

Circle 172 on postcard for more data

GRINDING ATTACHMENT HAS TRUE DEAD CENTERS

A highly accurate cylindrical o.d. dual-purpose grinding attachment uses true dead



centers which assure concentricity to 0.0001 total indicator reading. It is designed to serve as an inspection instrument, also.

Most notable features are a built-in sine plate and micrometer which permits grinding and inspection of tapers within seconds of an arc, spring loaded tail stock centers that also contribute to accuracy, and a micrometer range from 0.025 minus to 0.025 plus which eliminates the need for an expensive set of gage blocks.

Gebhart Machine Tools, Ltd.

Circle 173 on postcard for more data

TOOL SET SAVES TIME ON BORING OPERATIONS

Savings in set-up and machining time on miscellaneous non-repetitive stub boring operations may be effected with a packaged tooling assortment of bars, cutters, and various acces-

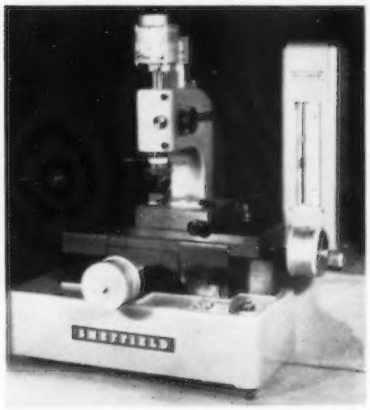
sory items. The assortment of seven basic tools is placed at the operator's finger tips. The tools can quickly and easily be interchanged, permitting the operator to handle flycutting work with bores ranging from 1¼ to 8 in., pencil boring from ⅜ to 1¼ in., and light extended boring up to 13-in. diam.

Giddings & Lewis Machine Tool Co.

Circle 174 on postcard for more data

HOLES LOCATED PRECISELY BY MEASURING MACHINE

In order to determine the precise location of holes in precision-made parts such as bearing



plates, the Precisionnaire hole coordinate measuring machine has been designed.

True location of holes is indicated, irrespective of diameter tolerances.

Two models are available; one will check hole center-distances in areas up to 6 x 6 in., and the other will accommodate areas to 10 x 10 in. Other sizes can be made to order.

Sheffield Corp.

Circle 175 on postcard for more data

worth asking for:

technical literature listed here is available without charge from the various manufacturers

Mechanical Force-Gage

Mechanical force - gage line is described in a six-page illustrated folder comprised of twenty-three action photographs of gages in actual use. The folder also includes complete specifications, dimensions, and capacities.

W. C. Dillon & Co., Inc.

Circle 226 on postcard for more data

Armature Winder

Page from catalog pictures and completely describes Model 46-MCA high-speed small armature winder with a time-saving self-resetting automatic counter. Technical details are given on armature types and sizes wound, size of wire, tension and motor equipment, counter, positive automatic stop, new instant automatic brake release, winding speeds, set-up time, mounting, and unique safe stationary armature.

Geo. Stevens Mfg. Co., Inc.

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Rocket Production Facilities

A complete listing of production facilities for missile and rocket programs is to be found in an illustrated 12-page brochure. It describes in detail the extensive machining and fabricating shops with sizes and capacities of all equipment listed. In addition, heat treating facilities, testing equipment, quality control, and procurement systems are described. Informative captions on the more than thirty illustrations show how the metals used in rocket and missile production are machined to exacting dimensions by experienced personnel.

The M. W. Kellogg Co.

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Magnetic Shields

Data Sheet 135 illustrates and describes the multi-laminae, smaller space-factor, hydroformed, complex configuration, non-shock sensitive, non-retentive, Netic - Co - Netic magnetic shields designed for guidance control devices.

Perfection Mica Co.

Circle 229 on postcard for more data

Turbonator

Eight - page illustrated technical report on the design and development of the turbonator, an air turbine driven a-c electrical power system for airborne applications. Information on the turbonator concept, design configuration, and developmental testing is included.

General Electric Co.

Circle 230 on postcard for more data

Contour Controls

Designed for fast, accurate, economical turning, facing, and boring of irregular contours, the latest tracer control system is fully explained and illustrated in a descriptive 20-page bulletin.

The Monarch Machine Tool Co.

Circle 231 on postcard for more data

Mechanical Equipment Manufacturing

This 12 - page brochure shows some of the equipment, some samples of finished work, and a complete list of machinery and equipment available for work on customer projects.

Tri-Kris Co., Inc.

Circle 232 on postcard for more data

Wire Sample Board

To assist designers and engineers in their wiring layouts, a sample board with actual samples of popular hookup and lead wires for commercial electronic equipment and components is available.

Included are samples of UL Approved, Canadian Standards Association Approved, and Lenz small diameter miniature lead wires.

Lenz Electric Mfg. Co.

Circle 233 on postcard for more data

Infrared Developments

A comprehensive 16-page report, on the application of infrared to military weapons systems and industrial control systems, details with text and pictures the striking effectiveness of infrared reconnaissance systems in mapping military and industrial target areas.

A recently declassified section reveals the role of advanced infrared developments for strategic and tactical situa-

worth asking for:

technical literature listed here is available without charge from the various manufacturers

Continued from page 71

tions, including missile guidance, bombing, wide-area reconnaissance, anti-submarine warfare, and countermeasures.

Reported in detail are: testing and calibration of the Navy's *Sidewinder* infrared detection system, an airborne infrared crevasse detector for scouting Arctic and Antarctic regions, how the railroad industry is using an infrared hot-box detective, and hot-forming titanium at Republic Aviation Corp. by use of an infrared pyrometer.

Servo Corp. of America

Circle 234 on postcard for more data

Numerical Drilling Control

"Enables One Drill Press to do the Work of 5!" is the title of a brochure describing the Digimatic control system for table positioning. An analysis of the system's cost saving advantages is presented. (The system adapts to existing machines.)

Automatic drilling of a typical part is illustrated step-by-step and a cost comparison with hand drilling is made. The brochure includes complete specifications of the system's three operating units: Tape Preparation Unit, Control Unit, and Compound Servo Tables.

Stromberg-Carlson Co.

Circle 235 on postcard for more data

Electric Welding

Linde *Metalworking Bulletin*, published bi-monthly by Linde Co., Div. of Union Carbide Corp., has a new look: 12-pages in two colors.

The *Bulletin*, designed to demonstrate the many industrial advantages of modern electric welding and cutting processes, contains an average of six concise articles in each issue. The easy-to-read publication presents interesting, cost-and-time saving applications of both manual and mechanized electric welding, spot welding, and cutting processes.

Linde Co.

Circle 236 on postcard for more data

Steel Lockers

Bulletin B-60, an 8-page, 2-color catalog describes the Penco 6000 Series steel storage lockers. Twelve locker styles are presented, and tabular charts are used to show the sizes available. Illustrations are shown of each locker model.

Penco Metal Products

Circle 237 on postcard for more data

Automated Deburring Machines

Twelve-page, two-color, illustrated catalog describes automated deburring machines.

The application of various types of deburring tools is discussed in detail, in an introductory section. Tools described include wire brushes, abrasive belts, abrasive disks, Tampico brushes, special brushes, polishing wheels, grinding wheels, files, and milling cutters.

Acme Manufacturing Co.

Circle 238 on postcard for more data

Synchro Tester

Data sheet describes Synchro Tester Model 3000, indicates the specifications, and presents the means of application for various uses.

Associated Missile Products Co.

Circle 239 on postcard for more data

Miniature Relays

Sensitive and high-speed miniature relays, as well as micro-miniature relays in both voltage-sensitive and current-sensitive models, are described in an available catalog. Besides specifications, there are adjustment schedules, dimensional, and circuit diagrams.

Iron Fireman Mfg. Co.

Circle 240 on postcard for more data

Investment Castings

An eight-page brochure on designing for investment castings covers such factors as fillets, holes, threads, wall thicknesses, and tolerances. One section is devoted to a discussion of ferrous and non-ferrous alloys which can be used for investment castings.

Photographs of nearly 100 investment cast parts are shown.

Casting Engineers. Inc.

Circle 241 on postcard for more data

Temperature Controls

Nine different types of temperature controls are described in a four-page, two-color condensed catalog.

Included are cartridge-style Thermoswitch units for general industrial use, midget, and miniature models for "tight-spot" applications; Detect-A-Fire units for overheat or fire protection; two different thermistor controllers; and a mechanical indicating controller. Temperature and current ratings are given for all models.

Fenwal Inc.

Circle 242 on postcard for more data

Closed Circuit TV System

Primary components of a closed TV system: camera, control, and monitor, are described and illustrated in a six-page, two-color folder.

Insul-8-Corp.

Circle 243 on postcard for more data

Manometers

Bulletin 500, eight-page, two-color brochure presents a description, design features, principle of operation, and suggestions for the use of manometers and servofollowers.

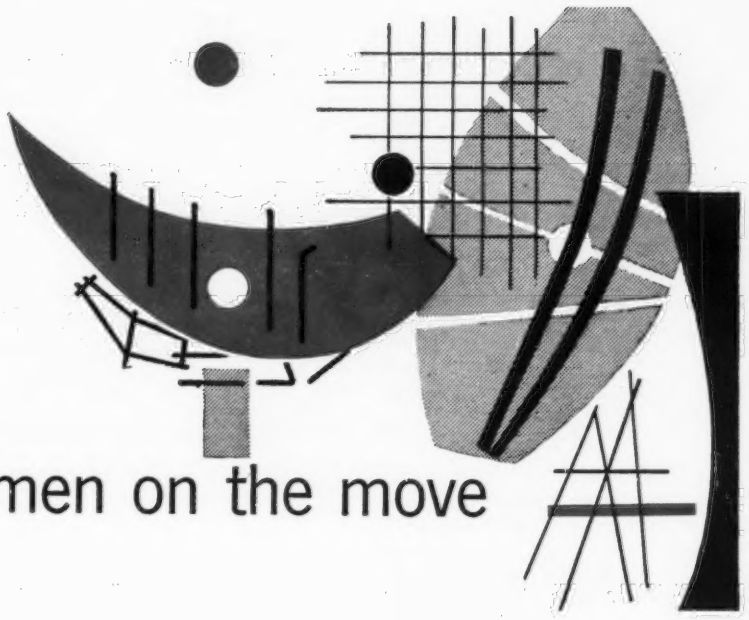
Exactel Instrument Co.

Circle 244 on postcard for more data

JOHN W. BRIGHTMAN
Nylok

JAMES A. ERDLE
Johnson & Hoffman

DR. JOHN MASON
Garrett Corp.



men on the move

JOHN W. BRIGHTMAN has been appointed chief product engineer of The Nylok Corp., Paramus, N. J.

EDWARD F. BRAUTIGAM is now Eastern Manager.

JAMES A. ERDLE has been made chief engineer of Johnson & Hoffman Manufacturing Corp., Mineola, N. Y.

R. A. MC NEILLY is works manager for Tube Reducing Corp., Wallington, N. J.

CARL S. SALTZMAN was named manager of Control Systems Co., a new division of Hancock Industries, Jackson, Mich.

DR. ROGER W. BURTNESS has become manager of engineering and research of Stewart-Warner Electronics.

DR. JOHN MASON received promotion to chief of preliminary design for AiResearch Manufacturing Div. of The Garrett Corp. at Los Angeles.

JAMES CRAWFORD was recently named manager of engineering.

CAPT. HOWARD THOMAS ORVILLE (retired) former chief aerologist for the U. S. Navy, has become vice president of Beckman & Whitley, Inc., San Carlos, Cal.

ELMER J. LELL was appointed vice president of Wall Colmonoy Corp., Detroit, in charge of Colmonoy Div. operations.

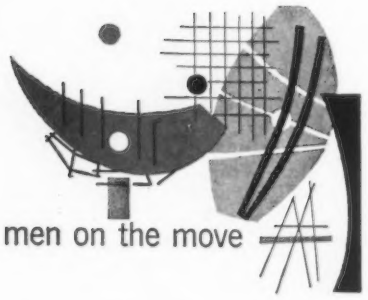
JERRY M. GRUITCH, director of research and development for the American Car and Foundry division of ACF Industries, Inc., will assume the newly created post of director of defense products.

DR. HENRY G. GIULIANI has joined Stavid Engineering, Inc., to lend his talents and experience to the company's efforts in the field of weapon systems engineering.

JOHN W. BLACK has been appointed plant manager of the Tucson, Ariz., operations of Hughes Aircraft Co.

LOUIS L. REASOR is assistant plant manager.

continued on next page



HAROLD E. FRANCIS has been named senior staff engineer of Chandler-Evans Div. of Pratt & Whitney Co.

JOSEPH D. THOMPSON has been appointed manager of aircraft instrument engineering at General Electric's Instrument Dept., West Lynn, Mass.

BRUCE H. SCHWARZE has been advanced to director of engineering for AC Spark Plug.

DONALD F. AYRES has been promoted to chief engineer of navigation and guidance.

LOUIS O. MITCHELL, production manager of Trans-Sonics, Inc., Burlington, Mass. has been elected vice president.

WILLIAM E. COBEY has been appointed director of helicopter engineering for Republic Aviation Corp.

GRAYSON MERRILL, director of engineering at the Fairchild Guided Missiles Div., Wyandanch, N. Y., has been appointed general manager.

EUGENE LAKS has been appointed director of purchases at Adler Electronics, Inc., New Rochelle, N. Y.

JAMES V. ROUGHAN has been elected president of Price Electric Corp. Frederick, Md.

MARCH W. OSBORNE, Jr. has been appointed to the newly created position of manager of propellant materials for B. F. Goodrich Chemical Co., Cleveland.

RICHARD H. OLSON was elected vice president in charge of the new Sundstrand Machine Tool Co., Turbo Div., which includes both the Denver operation and the American Machine & Foundry Co. Turbo division at Pacoima, Cal., which Sundstrand acquired recently.

KENNETH T. CAROLAN, general manager of Carmer Industries, Inc., Kenilworth, N. J., has been elected to the rank of vice president.

GORDON BRITT has been appointed sales manager.

JACK LEWIS has accepted the newly established position of director of manufacturing for The Garrett Corp.

DAVID G. PETTIGREW has been promoted to manager of the Baltimore branch of Whitehead Metal Products Co., Inc.

WILLIAM N. SNOUFFER has been promoted to project manager of the Plato anti-missile missile system by Sylvania Electronic Systems, a division of Sylvania Electric Products, Inc., at Waltham, Mass.

W. G. LUNDQUIST, an outstanding expert in engine development, has been retained by Reaction Motors, Inc., Denville, N. J., as technical consultant and advisor on the Pioneer advanced liquid propellant rocket engine.

ALBERT T. BOTH, former works manager of the Cleveland Mill Div. of Chase Brass & Copper Co., a subsidiary of Kennecott Copper Corp., has been appointed assistant vice president of operations.

WILLIAM A. ZIEBELL has been advanced to plant superintendent for Chicago Aerial Industries, Inc., Melrose Park, Ill.

RICHARD H. OLSON
Sundstrand

WILLIAM N. SNOUFFER
Sylvania

WILLIAM A. ZIEBELL
Chicago Aerial Industries

industry notes

Philly Hosts Tool Show

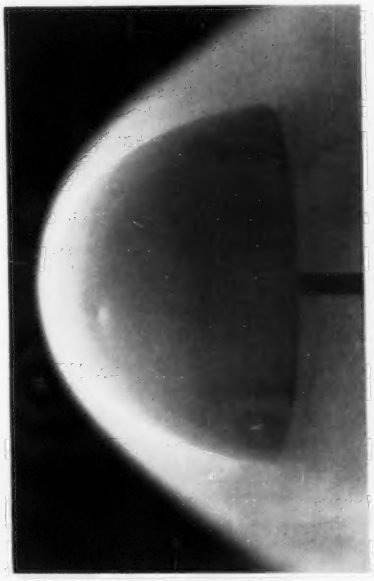
The 1958 Tool Show is the twelfth and "biggest one yet," running in conjunction with the American Society of Tool Engineers' 26th Annual Convention, in Philadelphia, May 1-8.

Some 40,000 manufacturing men from all over the country are attending the event. They have plenty to occupy their time while here. The exhibits of equipment, machinery, accessories, and processes present new ideas, techniques, and approaches which should stimulate.

More than 100 technical papers, covering all phases of manufacturing, will be presented. Thirty planned tours of industrial plants in Delaware Valley, U.S.A. will give the participants an opportunity to see the various tools and techniques in practice.

PLANE DESIGNED FOR FLIGHT IN SPACE

Designed to be the first airplane to penetrate outer space is the X-15 rocket-powered airplane. It is under development at the Los Angeles Div. of North American Aviation, Inc., for the Air Force, Navy, and National Advisory Committee for Aeronautics. The craft is shown here for the first time in an official artist's conception.

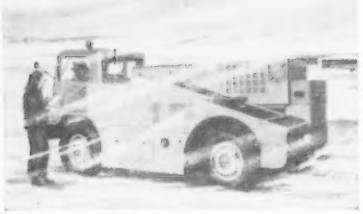


Escape Speed Exceeded in USAF Wind Tunnel

Escape velocity, the minimum speed required to propel an aircraft or missile out of the earth's gravitational field into space, has been exceeded in a wind tunnel called Tunnel Hotshot II, at the U. S. Air Force Arnold Engineering Development Center, Tullahoma, Tenn.

The test run peak lasted about one-tenth of a second during which an airflow of approximately nine miles per second, 32,400 mph, was achieved. This

HUNTER ENGINE HEATERS



for military applications at sub-zero temperatures

- designed and produced in accordance with military requirements.
- for starting internal combustion engines at sub-zero temperatures, cold starts to −65°F.
- standard winterization gear for military vehicle engines, generator sets, compressors, hydraulic test stands, battery starting carts, other ground support and special purpose equipment applications.
- burn any type gasoline or JP-4 fuel.
- BTU/Hour range: from 30,000 to 90,000 input, utilizing both uncontaminated air and exhaust.
- compact, light-weight, high capacity units for delivery of high temperature, high-volume air as required for specific applications.

Other Hunter military equipment: space and personnel heaters; instant lighting torches, refrigeration units.

GET THESE BROCHURES TODAY!

for complete specifications and details

HUNTER MANUFACTURING CO. 30537 AURORA RD. SOLON, OHIO

HEATING AND REFRIGERATION SYSTEMS

Circle 18 on Inquiry Card, page 65

industry notes

is nearly twice the speed required to place a satellite in orbit. It is the first time that escape velocity, seven mi/sec, has been reached in a wind tunnel.

Incandescence surrounding the missile nose (see illustration) in Tunnel Hotshot II is caused by friction of high velocity air on test object, in this case a theoretical missile nose. Dent in nose was caused by piece of nozzle throat torn off by high velocity air during test run.

Although the test flow lasted but a fraction of a second, special rapid-response instruments, developed by ARO scientists, made possible the recording of the extreme flight conditions. Temperatures exceeding 40,000°F are caused by the friction of the air passing over the model; and the electrical discharge that heats the air creates pressures up to more than 30,000 psi. Longer runs under these conditions are impossible for the extreme temperatures and pressures would cause tunnel components to melt or vaporize.

Observation Domes Rushed For White Sands

To track missiles satellites, and future manned space vehicles, the Cook Electric Co. of Chicago is rushing to completion an unspecified number of "Astrodomes." These automatic, mechanical housings for highly complex and valuable instruments will be shipped to the White Sands Proving Grounds in New Mexico.

They are built of re-inforced plastic. The semi-spherical roof revolves 360-degrees on a track; its dome splits automatically to any specified opening required to view the skies.

A special reflective finish plus insulation make the units adaptable for virtually any climate. They will be used primarily for tracking missiles in flight, and plotting flight paths of missiles and future space vehicles.

U. S. Army Orders Hughes 269A Helicopter

Production is under way on the first five Hughes Model

269A helicopters ordered by the U. S. Army.

This two-man helicopter has an empty weight of only 890 lb and carries a useful load of 660 lb.

It has a top speed of 90 mph, and a cruising range of 150 mi. It is powered by a 4-cylinder, air-cooled 180 hp Lycoming engine, held in place by four bolts and easily removed for maintenance.

The helicopter was developed without aid of a military contract. It is being made available first to the armed services but it also holds promise for industries and governmental agencies.

Illustration is artist's drawing of the craft.

Man-Made Men Called 'Anthropomorphs'

Man - made men called 'Anthropomorphs' are used by

North American Aviation human factors engineers in perfecting systems for getting human pilots back to ground safely in case of aircraft failure. Dummies have rubber skins, and are made to conform to shape, size, and weight of actual human pilots. Electronic equipment in chest and stomach cavity records a wide variety of information, knowledge of which is required to provide for pilot safety during high speed bailout.

Sources Conflict Over Heat Formation Values Of Lithium Perchlorate

Propulsion engineers designing solid fuel rocket engines should be aware of a disagreement which exists on the heat of formation values for lithium perchlorate ($LiClO_4$).

Lange's *Handbook of Chemistry* lists a value of —106 K cal/mole (pp. 1599 and 1695). The *Handbook of Chemistry and Physics* omits $LiClO_4$ entirely in the heat of formation tables.

Foote Mineral Co. recalculated the heat formation for this proposed ingredient of solid rocket fuels as —98.0 K cal/mole at 25°C. The revised figure was derived by using heat of formation data at infinite dilution as listed in National Bureau of Standards Circular 500.

Using this figure, the heat of formation of anhydrous $LiClO_4$ was actually measured at —91.8 K cal/mole at 25°C.

Fury Jet Has Rocket In Tail

Rocket-power augmented *FJ-4F Fury*, featuring a new North American Aviation rocket engine, the AR-1, is being tested by pilots of the Naval Air Test Center, Patuxent River, Md.

Although no performance gain details were revealed, the Navy describes early results as "significant" improvements over the *Fury's* normal near-sonic speed and 50,000 ft altitude.

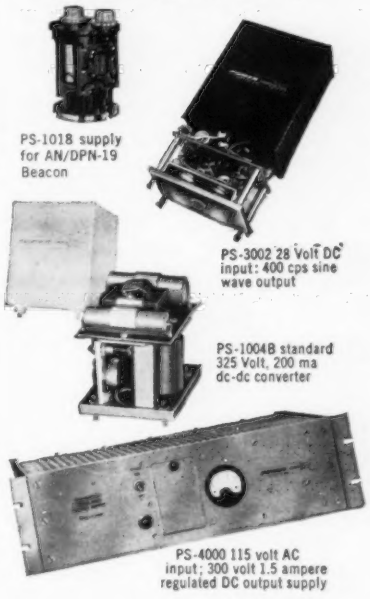
The AR-1, which operates in conjunction with the standard turbo-jet engine, burns hydrogen peroxide and conventional JP-4 fuel. The engine was designed and developed by Rocketdyne, a division of North American Aviation. It is being test flown by the Navy in the

standard *FJ-4* modified, at Columbus, to serve as experimental test bed aircraft.

In initial tests at Columbus, the AR-1 rocket engine used a mono-propellant fuel, hydrogen peroxide, as its source of power, but present tests utilize the bi-propellant mixture. Peroxide is easily storable and ready for instant use by interceptors on alert status.

Military reliability in

SEMI-CONDUCTOR POWER CONVERTERS


PS-1018 supply for AN/DPN-19 Beacon
PS-3002 28 Volt DC input: 400 cps sine wave output
PS-1004B standard 325 Volt, 200 ma dc-dc converter
PS-4000 115 volt AC input; 300 volt 1.5 ampere regulated DC output supply

Power Sources units are now in production missiles

Complete range of sizes, types and capacities for military and commercial requirements:

★ DC to AC available in any power up to 1500 watts . . . square or sine wave output.

★ AC to DC available with voltages up to 500V, and currents to 3 amps . . . DC Regulation to 0.1% . . . Impedances to .05 ohms . . . Over-all efficiencies 70-75%.

★ DC to DC available in combinations of the DC to AC and AC to DC ratings shown above.

★ Military Reliability is assured by extremely conservative designs and the use of the best, pretested military grade components and advanced semiconductor techniques. Meet MIL-E-5400 and MIL-E-8189.

SEND FOR TECHNICAL DATA

POWER SOURCES, INC.
Burlington, Massachusetts
BRowning 2-3005

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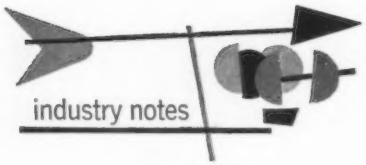

INDUSTRY STATISTICS

Source: Bureau of Labor Statistics

EARNINGS OF PRODUCTION WORKERS

Complete Aircraft Plants

Month	1957 Average Earnings Hourly	1957 Average Earnings Weekly	1957 Real Weekly Earnings‡	1957 Average Hrs. per Week	1956 Average Earnings Hourly	1956 Average Earnings Weekly	1956 Real Weekly Earnings‡	1956 Average Hrs. per Week
January	$2.31	$97.71	$82.66	42.3	$2.19	$91.32	$79.68	41.7
February	2.32	97.21	81.90	41.9	2.20	91.74	80.05	41.7
March	2.34	98.05	82.46	41.9	2.21	91.94	80.16	41.6
April	2.35	97.76	81.94	41.6	2.26	94.02	81.83	41.6
May	2.32	92.80	77.59	40.0	2.27	94.43	81.83	41.6
June	2.33	92.97	77.35	39.9	2.27	93.75	80.68	41.3
July	2.34	93.13	77.09	39.8	2.29	95.49	81.61	41.7
August	2.37	95.04	78.54	40.1	2.30	96.60	82.70	42.0
September	2.37	94.80	78.29	40.0	2.30	96.60	82.49	42.0
October	2.38	95.20	78.61	40.0	2.31	96.79	82.23	41.9
November	2.40	95.52	78.55	39.8	2.31	97.25	82.55	42.1
December	2.41	97.12	79.87	40.3	2.32	97.67	82.77	42.1
Average	$2.35	$95.65	$79.57	40.7	$2.27	$94.89	$81.66	41.8

Aircraft Engine and Parts Plants

Month	1957				1956			
January	$2.38	$102.82	$86.99	43.2	$2.25	$96.08	$83.84	42.7
February	2.37	102.62	86.45	43.3	2.23	94.55	82.50	42.4
March	2.37	101.20	85.11	42.7	2.23	92.99	81.07	41.7
April	2.37	100.25	84.03	42.3	2.22	92.35	80.37	41.6
May	2.33	95.06	79.48	40.8	2.24	93.18	80.74	41.6
June	2.36	96.76	80.50	41.0	2.27	94.89	81.66	41.8
July	2.36	96.29	79.71	40.8	2.28	96.22	82.24	42.2
August	2.41	96.16	79.47	39.9	2.29	97.55	83.52	42.6
September	2.42	95.11	78.54	39.3	2.32	99.76	85.19	43.0
October	2.45	96.78	79.92	39.5	2.32	99.76	84.76	43.0
November	2.46	97.17	79.91	39.5	2.33	99.26	84.26	42.6
December	2.52	100.30	82.48	39.8	2.39	104.92	88.92	43.9
Average	$2.39	$98.47	$81.92	41.2	$2.28	$96.67	$83.19	42.4

‡—Weekly earnings adjusted to Consumers' Price Index.

EMPLOYMENT IN THE AIRCRAFT AND PARTS PLANTS

Month	Complete Aircraft Plants 1957	Complete Aircraft Plants 1956	Aircraft Engine and Parts Plants 1957	Aircraft Engine and Parts Plants 1956	Aircraft Propellers and Parts 1957	Aircraft Propellers and Parts 1956	Other Aircraft Parts and Equipment 1957	Other Aircraft Parts and Equipment 1956
January	546,800	476,800	181,000	154,300	19,700	14,900	144,000	123,500
February	554,900	479,400	183,800	156,800	20,100	15,200	146,000	126,000
March	557,200	470,300	184,200	159,000	20,400	15,300	146,800	128,000
April	557,000	475,100	183,300	160,300	20,600	15,500	148,200	127,700
May	558,300	477,500	179,700	160,700	20,400	15,900	148,500	129,600
June	556,200	490,500	178,900	162,900	20,600	16,400	149,900	129,400
July	553,900	500,900	176,900	164,300	21,000	16,800	150,200	131,900
August	542,400	509,300	173,000	166,000	20,500	17,100	149,900	135,100
September	529,500	515,600	169,700	170,600	20,600	18,000	148,700	137,000
October	516,700	522,100	165,500	173,900	20,600	18,500	144,400	138,900
November	489,000	531,600	158,200	177,700	20,100	19,000	138,900	142,400
December	476,900	540,000	155,100	181,100	20,300	19,600	134,900	143,900
Average	536,600	499,100	174,100	165,600	20,400	16,900	145,900	132,800

PRODUCTION WORKERS IN THE AIRCRAFT AND PARTS PLANTS

January	362,600	323,200	116,000	98,300	13,300	10,100	103,300	90,000
February	367,300	322,600	117,600	99,600	13,600	10,300	104,100	91,600
March	367,200	313,700	117,900	100,900	13,900	10,400	104,100	92,200
April	366,500	314,500	116,800	101,000	14,100	10,500	104,200	92,100
May	366,800	313,700	113,200	101,900	13,900	10,700	104,400	93,300
June	363,200	322,700	112,300	102,500	14,200	11,100	104,200	93,300
July	357,800	324,100	109,000	101,800	14,400	11,100	103,800	93,800
August	351,400	333,000	104,500	102,600	13,900	11,300	103,700	96,200
September	341,000	337,700	102,900	106,500	14,000	12,000	102,700	97,800
October	334,800	343,000	100,300	109,700	14,100	12,400	99,500	98,900
November	315,400	351,900	95,400	112,800	13,700	12,800	94,900	101,700
December	309,500	358,000	93,400	115,100	13,900	13,200	91,900	102,900
Average	350,300	329,800	108,300	104,400	13,900	11,300	101,700	95,300

'Thermostat' Rides High On Explorer Satellite

Since the successful January 31 launching of the first American earth satellite, a ceramic coating has played an important role in the orbital flight of the Army's *Explorer*.

The leading surfaces of the satellite package are partially covered with an aluminum oxide coating called Rokide A. Scientists at Jet Propulsion Laboratory, California Institute of Technology, have used this coating to assist in controlling the temperature of the instrumentation inside the satellite. It was sprayed on in stripes along the outside of the instrument vehicle from the nose cone down to the fourth stage rocket motor section. This is the same brand of pure aluminum oxide sprayed on the inside skins of rocket nozzles. Rokide A is made by Norton Co., Worcester, Mass.

Oscillating in space at 18,000 miles an hour, *Explorer* is at Nature's mercy between 200 and 1600 miles outside the earth's atmosphere. When it is on the dark side of Earth, the satellite radiates heat to the coldness of empty space. When on the sun side of Earth, it absorbs heat at a terrific rate. This temperature differential totals close to 800 degrees: from about 150°F below zero, on the cold side; to nearly 600°F above, on the hot side. As the satellite circles the earth once each 118 min., these wide fluctuations in temperature occur every hour. The resultant thermal stress and strain is enormous.

Jet Propulsion Laboratory scientists have controlled this range between hot and cold by coating the instruments section housing the high and low-power transmitters with stripes of Rokide A. The nose cone is treated in the same way.

The forward shell of the satellite is twenty-five per cent covered by eight equally spaced stripes of Rokide A, each one-

WHICH SEAL WILL SOLVE YOUR PROBLEM?

Seals drawn to same scale.				
Type of Seal	**Standard**	**Modified**	**Bellows**	**Shaft Surface**
Pressure (PSI)	1000	500	250	75
Speed (FPM)	15,000	15,000	15,000	15,000
Temperature (°F)	350° to 450°	—360° to 350°	—360° to 700°	500° to 700°
Uses	Fluids including aviation fuel, synthetic lubricants, etc.	Rocket motors, HNO_3, H_2O_2, NPN, LOX, Ethylene Oxide	Applications calling for all-metal, high temperature sealing	Sealing gaseous mediums in a minimum amount of axial space
Send for	Bull. #7	Specially enginered	Bull. #18	Bull. #19

CAUTION: Maximum conditions indicated for each type do not necessarily imply that all are available in a single seal. Sealol engineers will gladly recommend the seal best suited to the operating conditions of your particular application. Write today . . . no obligation, of course!

SEALOL CORP
425 Post Rd., Providence 5, R. I.

SEALOL

Circle 19 on Inquiry Card, page 65

STAINLESS
FlexDucts & Bellows

- which handle high temperature corrosives
- which withstand drastic pressure changes, vibration & sinuous alignment

. . . designed and fabricated by U. S. Flex

Write for technical data

U.S.Flex

U. S. FLEXIBLE TUBING CO.
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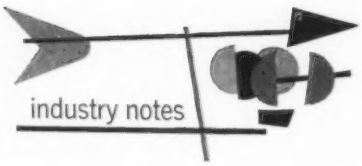


quarter inch wide. It is this striping which keeps the temperature range inside the satellite between 50° and 86°F, and protects the sensitive electronic components carried on board.

Jupiter Gas Turbine Helps Service Sea Master

Solar Jupiter gas turbine will be installed on boats and tenders for on-the-water servicing of the SeaMaster.

The unit will supply compressed air to start the SeaMaster's four jet engines, supply air for the seaplane's air conditioning system, and provide electrical power while on the water.

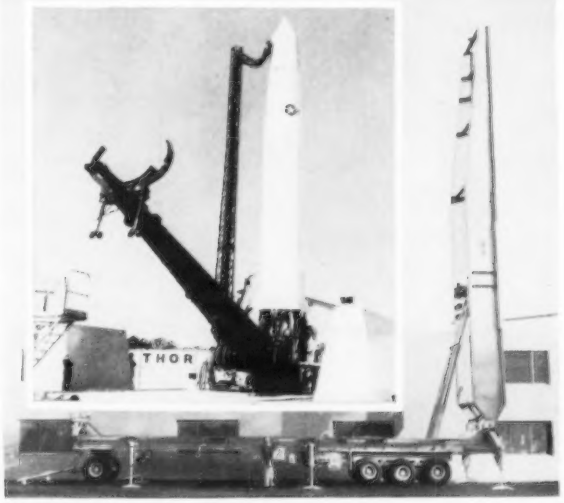
Launching Equipment Contracts Awarded

Ordnance Div. of Food Machinery and Chemical Corp., San Jose, Cal., and Locomotion Engineering Inc., Sunnyvale, Cal., are engaged in the production of ground handling equipment for missiles.

A production contract for ground handling and launching units of the USAF Intermediate Range Ballistic Missile, *Thor* (see insert), was awarded FMC by Douglas Aircraft Co.

Locomotion Engineering is under contract to Lockheed Missile Systems Div. to produce handling equipment for the Navy *Polaris* fleet ballistic missile.

Basic ground handling equipment is the erector-transporter. This huge trailer is used to transport the missile to the launching site, then leveled on outriggers to erect the missile to vertical firing position on the



launching mount or pad. Missile is then fueled.

FMC is also building a power-pack trailer which contains all the hydraulic and electronic mechanisms needed to actuate the initial steps of the firing sequence.

The *Thor* is a 1500-mi range, land-based, surface-to-surface missile, powered by liquid fuel.

The *Polaris* is an intermediate range, fleet ballistic missile, and powered by solid propellant.

continued on page 82

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Progress

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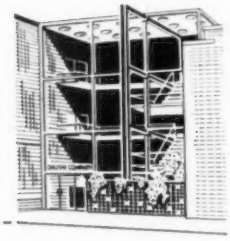

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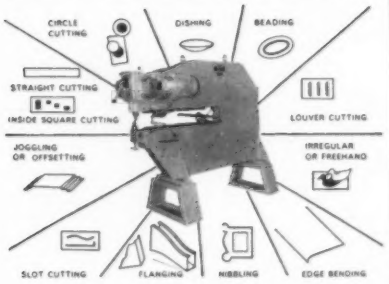

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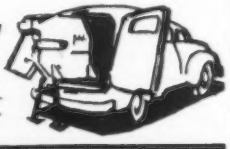

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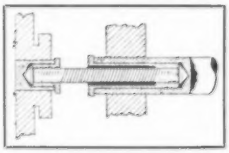
FLEXIBLE SHAFT COUPLING FOR THE AIRCRAFT INDUSTRY



Coupling is used for the transmission of power or control of movement between parts located close together in a piece of equipment. It is not a separate type of flexible shaft but rather an added application of flexible shafting.

The coupling can be composed of either power drive or remote control flexible shafting although the latter is generally used due to the added advantage of its ability to rotate both clockwise and counter clockwise. Generally used between two units which are but a few inches apart, coupling may transmit power between any two parts regardless of their relative positions.

For example, the diagram above shows an advantage in using small lengths of flexible shafting in a coupling application. Although the drive end and the driven end are not exactly in line, the coupling compensates for the difference in alignment between the two.

Many manufacturers use flexible shaft coupling even where parts may be connected by solid shafts because of the savings realized in the initial and the maintenance costs as well as in time and labor.

For complete information on how flexible shaft couplings may help improve your product design, write F. W. Stewart Corporation, 4311-13 Ravenswood Avenue, Chicago 13, Illinois.

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industry notes

Jindivik at Woomera

missile recovery

Catch a falling missile; it's being done "way down under" at Woomera, a rocket range in southwest Australia.

The area is very sparsely populated for 1250 mi to the coast and another 2500 mi is available over the water.

In the 3300 sunshine hours each year, much time is devoted to testing of missiles.

Every thing a missile does from blast-off to impact with target, or Earth, is of great interest and value to the researchers. Its behavior during ascent and descent is photographed and data is recorded by telemetry.

Techniques developed in guided flight testing include those concerning target aircraft and recovery of missiles.

Targets are essential to the testing and exercising of missiles. Two target types are used at Woomera (about 300 miles from Salisbury): obsolete *Meteor* fighters and the pilotless *Jindivik*.

Performance of the *Meteor* cannot be developed to represent newer types of possible targets, but it has the advantage of having a pilot for test work. Thus techniques may be developed in the first place with a pilot in charge and certain conditions of flight can be more easily investigated. The *Jindivik*, on the other hand, can be developed very easily to meet changing performance aspects because sufficient space and strength were designed into it. Basically, both types employ auto-pilots to stabilize the craft, while a simple radio-link gives on-off commands. Such commands change the auto-pilot datum and, consequently, flight path, to a limited degree.

It is possible to operate a *Jindivik* at 50,000 ft for a period of one hour. Design specification called for a simple monoplane capable of taking off from a trolley and landing on a skid, and to be powered by a cheap expendable engine. The Armstrong-Siddeley Viper turbo-jet with a specified life of 10 hr was chosen.

In practice the target has been found very reliable with simple handling characteristics. At first a loss rate of 1 in 5 was anticipated but steady progress gave a figure of 1 in 18 during 1957. This improvement has been obtained by great attention to detail during servicing.

Changing the engine fuel system design has guaranteed a life of 25 hr. Later-mark engines give greater thrust and this, combined with a span extension of 6 ft and smaller camera pods, will allow higher speeds and altitudes up to 60,000 ft.

MISSILE RECOVERY continued

In the evaluation of ground-to-air missiles, failures and malfunctions of elements of the missile itself are not easily traced by telemetry, therefore, post firing inspection is always a valuable check. Various recovery systems have been developed, each with a special purpose or application for preserving the missile and instrumentation for visual inspection.

The BREAK-UP technique has been used with explosive rings to break the aerodynamic shape into two that will tumble. If the break occurs in the right spot impact velocity can be reduced considerably. Often this method is used in conjunction with a parachute on a part of the body.

PARACHUTE recovery of the whole missile may be possible, but this generally calls for a cluster of chutes and possibly air brakes as well, therefore, sufficient storage space must be available. A spiked nose is useful here because it stops side drift when contact is made.

Speeds no greater than 20 to 25 ft/sec are max for complete intact recovery, and generally it is not possible to get such low velocities with gear carried on the missile.

PARAVANE, a unique method of complete air recovery, is now being developed and so far an encouraging degree of success has already been obtained. For this the missile is fitted with a parachute capable of reducing velocity to about 200 ft/sec and separated from the body by 100 ft of cable. An aircraft having detection gear and towing an aerial version of the naval paravane flies a predetermined pattern. At a suitable time the pilot positions his aircraft to intercept the falling missile. When timed correctly

the paravane cable, which is 250 ft long, encounters the parachute line. The relative sliding action causes two grapples to engage and from this point a constant friction winch in the aircraft starts paying out cable until the missile is stopped relative to the aircraft; winching-in then commences.

Once the missile is in tow, there are two alternative methods of getting it down to the ground.

It is possible to arrange the grapples so that a much larger parachute is slipped to the missile which then falls away to a safe landing.

The other way is to fly the aircraft low over a depression in the ground across which a wire has been stretched. The grapples will engage with this so that the shock breaks a weak link and leaves the missile suspended on the wire.

Possible oscillation on the slipstream makes it inadvisable to bring the missile right up to the aircraft for fitting a parachute or towing.

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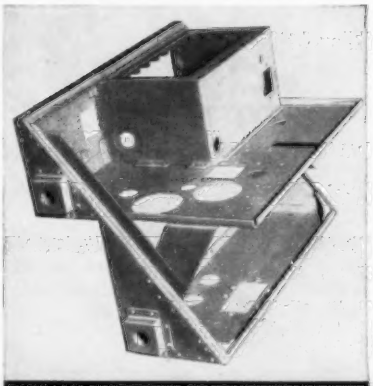

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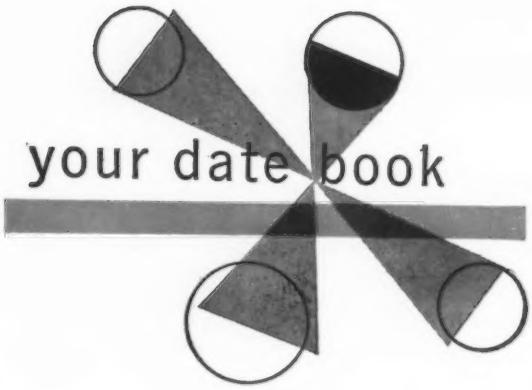

what	a.s.t.e. tool show
who	american society of tool engineers
where	convention hall, philadelphia, pa.
when	may 1-8

◆

what	fourth national flight test instrumentation symposium
who	instrument society of america and flight test committee of ISA aeronautical div.
where	park sheraton hotel, new york city
when	may 5-7

what	national midwestern meeting on guided missiles (classified)
who	institute of the aeronautical sciences
where	hotel chase, st. louis, mo.
when	may 12-14

◆

what	national conference on aeronautical electronics
who	institute of radio engineers
where	biltmore hotel, dayton, ohio
when	may 12-14

◆

what	southwest metal exposition and congress
who	american society for metals
where	dallas, texas
when	may 12-16

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what	spring meeting
who	society for experimental stress analysis
where	hotel manger, cleveland, ohio
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what	17th annual national conference
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- ¼" maximum capacity
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